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DEPARTMENT OF COMMERCE

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INFORMATION CIRCULAR

MINING METHODS AND COSTS AT THE MONTREAL MINE, MONTREAL, WIS.

BY

O. M. SCHAUS

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MINING METHODS AND COSTS AT THE MONTREAL MINE, MONTREAL, WIS.[1]

By O. M. Schaus[2]

INTRODUCTION

This paper is one of a series prepared by the Bureau of Mines and deals with the Montreal mine, one of only two active properties in Wisconsin on the Penokee-Gogebic range.

The purpose of this paper is to describe the conditions of occurrence of iron ore in a particular property and to present sufficient details of equipment and production methods to convey to the unacquainted operator a correct idea of the mining practice.

ACKNOWLEDGMENTS

The author is indebted to the Montreal mine organization for much of the detailed information herein.

HISTORY

The property of the Montreal Mining Co., known as the Montreal mine, is located on the Wisconsin end of the Gogebic range. The west branch of the Montreal River crosses the property 3/4 mile west of the east boundary line.

Iron ore, in the form of hematite, was discovered within the present property limits in 1885. The late E. W. Oglebay of Cleveland, was active on the range at the time and became interested in the first efforts to produce ore from the new discovery by means of a small open pit. The Montreal Mining Co. was organized in 1894 and under the management of Oglebay, Norton & Co. of Cleveland has increased its holdings to embrace 2¼ miles of the iron formation.

The growth of the property to a production capacity in excess of a million tons of ore per year has been steady and uninterrupted, except in the year 1921. The history of exploitation may be conveniently divided into three periods, although these overlap too much to be clearly defined.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6369."

2 - One of the consulting engineers, U. S. Bureau of Mines.

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The first period covered the years 1886 to 1912, during which time 3,500,000 tons were produced. The first underground mining was carried on through numerous vertical shafts at isolated spots along the strike. As the workings became more extensive and it became known that the ore persisted in depth, shafts were sunk on the quartzite footwall and followed its irregularities to considerable depth. At the close of this period there were two working shafts on the west end of the property called the Montreal mine and two shafts on the east end of the property called the Ottawa mine. All equipment was steam operated during this period. Open-stope and room-and-pillar mining methods were used.

The second period covered the years 1912 to 1929, during which 12,000,000 tons of ore were produced. This period was marked by completion of a central shop building and two 5-compartment steel-lined, inclined shafts in the quartz slates 300 feet south of the footwall. These shafts replaced the four old shafts and were operated independently as the Montreal and Ottawa mines.

The Montreal shaft was steam equipped for a capacity of 2,000 tons per day from a maximum depth of 4,000 feet. The Ottawa shaft was electrically equipped throughout for a capacity of 1,000 tons per day from a maximum depth of 3,000 feet. At the time of the re-equipment, the Montreal mine was at a depth of 1,500 feet, the Ottawa at 1,000 feet.

During the early part of the second period the significance of the great longitudinal or bedding fault became known. It was realized that conditions favorable to ore deposition in the "foot" formations existed in the "hanging" formations in displaced positions. Systematic exploration on this theory exposed the ore bodies, and 45 per cent of the production of the property has been from the "hanging" since their discovery.

A comprehensive geological study in 1920 revealed possibilities of greater ore bodies at depth. An exploration program confirmed the geological deductions and determined the lateral limits of the ore to a considerable depth. There followed a study of deep mining, of which the primary question was whether or not a shaft at each end of the property should be continued or a new shaft should be sunk to handle the total production from the property.

The determining factors in favor of a new shaft were subsidence in the vicinity of the Montreal shaft and the fact that at the center of the property was a block of unexplored ground into which the Montreal ore bodies were pitching. Subsidence has not affected the Montreal shaft as yet but is in evidence over a large area immediately west of the shaft, north of the footwall. There has been no movement south of the footwall, but with increased ore areas at much greater depth buckling of the quartz slates may occur.

In recent years a vertical shaft, located centrally and where it would be unaffected by subsidence, has been sunk to a depth of 3,000 feet and electrically equipped to handle the total tonnage from the property. Connections from this shaft to the underground workings are now completed, and the mine is entering the third period of operations with one central hoisting shaft and two auxilliary shafts for handling men and materials. The average vertical depth of mining is 2,000 feet; the deepest mining is 2,550 feet.

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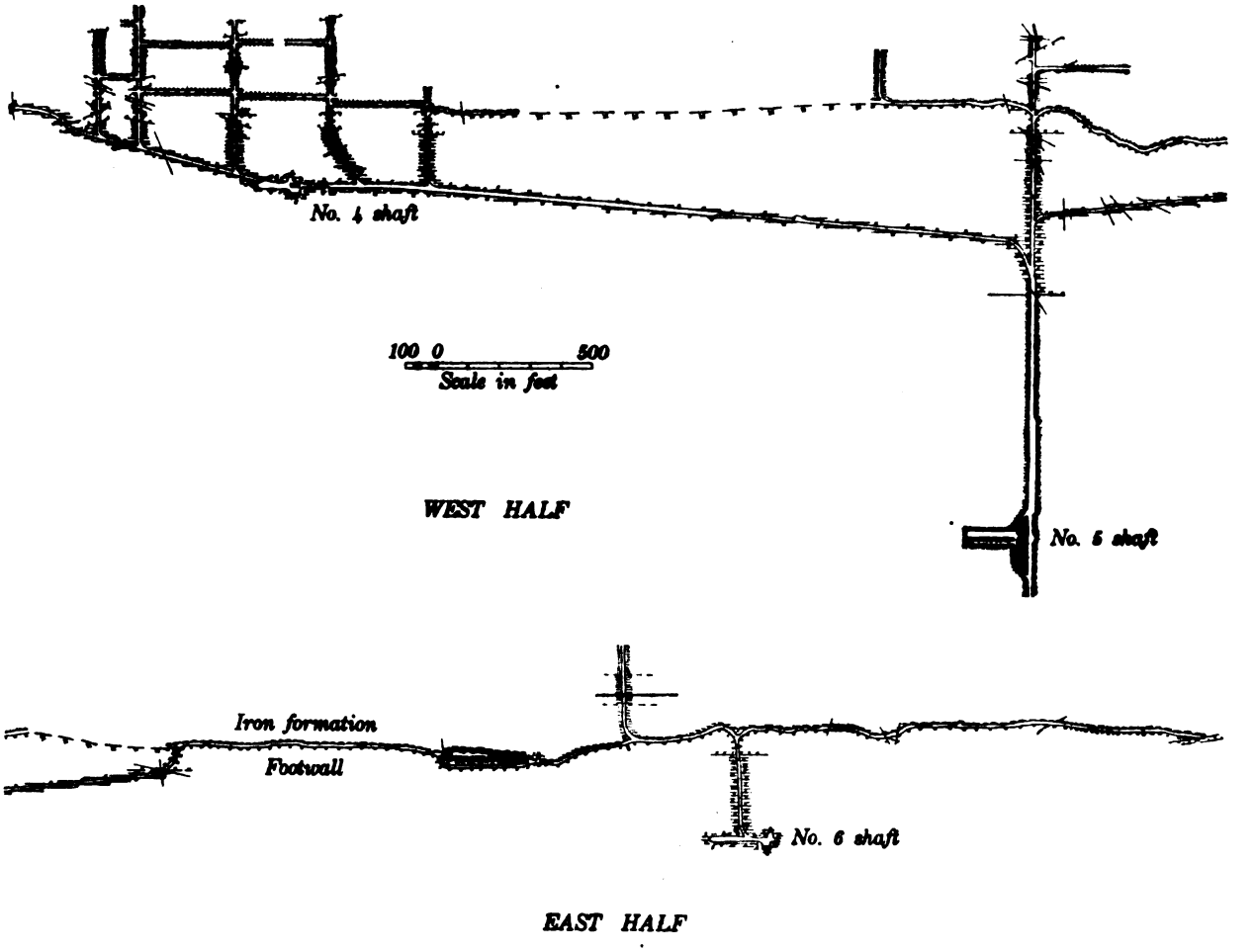

Figure 1. – Plan of main level

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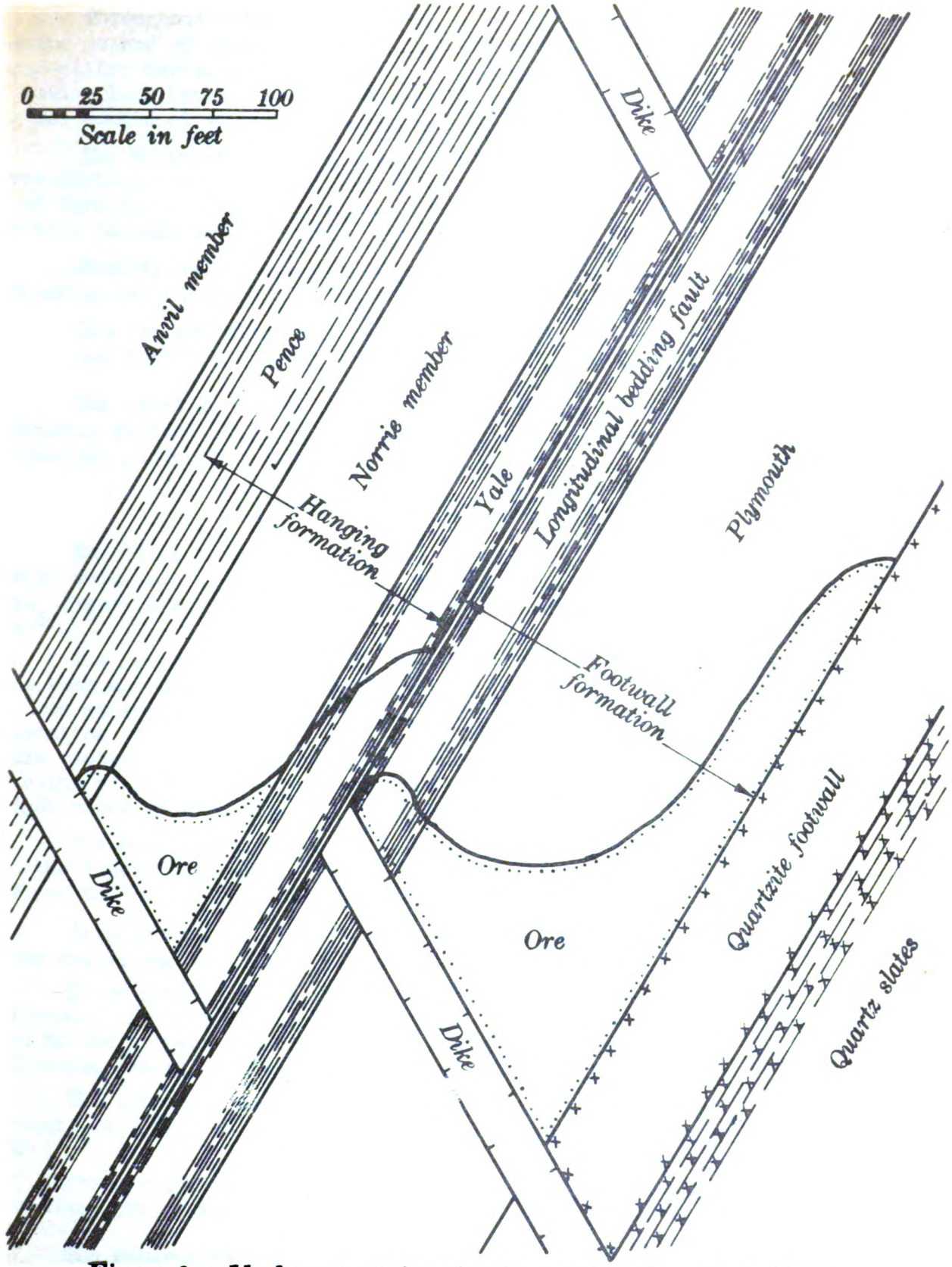

Figure 2. — *Ideal cross section showing various iron formations*

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Throughout this period on the east end of the property an overhand open-stope method of mining has been used. On the west end of the property the room-and-pillar method was supplanted by chute caving, which was followed by sublevel caving into branch raises. Upon development of the slusher, sublevel caving was continued without branch raises.

The Montreal mine has been and still is a property of large ore reserves divided into comparatively small ore bodies scattered over a great expanse of territory. Figure 1, a plan of the 27th level, is an average horizontal section through the property.

Conditions of ore occurrence in the past may be further explained by the following records:

0.4 ton ore mined per square foot explored footwall area
4.0 tons ore mined per square foot developed footwall area

The great amount of exploratory and development work, shaft, hoisting, and equipment expense in the past has been the principal factor in determining the economical production rate from the property.

GEOLOGY OF MONTREAL MINE

The "iron formation" consists of a series of sedimentary rocks, the members of which are easily identified and are extremely regular both in strike and dip. Figure 2 shows the relative position and thickness of the various members.[3]

The generally accepted theory of ore deposition is that "the enrichment has been accomplished by circulating waters through oxidation and hydration of the iron minerals, solution and removal of silica, and to some extent the transportation of iron from one part of the formation to another". In agreement with this theory, conditions most favorable to ore occurrence have been at the intersection of intrusive dikes with impervious members of the formation and in the neighborhood of cross faults, which break up the formation.

The hard quartzite footwall and middle band of Yale slates are in general the impervious members of the formation. The productive horizons are the lower Plymouth, upper Yale, Norrie, and lower Pence.

As a general rule the ore bodies are clean cut; there is no gradation belt from ore to the inclosing rocks.

Three grades of ore are produced, a Bessemer, a non-Bessemer, and a manganiferous. No rule may be stated to show the relation between grade and location on the property, except that manganiferous ores are found in the Plymouth member in the eastern third of the property.

The intrusive dikes form, with the footwall, a trough in general pitching eastward at 20°. The dikes are very regular and persistent throughout the property.

Cross faults are always present in the vicinity of ore bodies. These faults shatter the formation and usually have but small displacement.

The remarkable regularity and continuity of the members of the formation have been disturbed by only one fault of importance, called the great

3 - W. O. Hotchkiss, Geology of Gogebic Range: Eng. and Min. Jour., Sept., 1919.

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longitudinal bedding fault, which is as regular and dependable as the members of the formation.

The longitudinal bedding fault has a throw of approximately 800 feet along the strike and 500 feet along the dip of the bedding, the movement taking place throughout the property in the middle slates of the Yale member. The fault zone varies in thickness from inches to several feet and is generally easily recognized. The iron formation north and south of the fault zone is locally designated as "hanging" and "foot" formation respectively.

The bedding fault movement happened after the dike intrusions. North of the fault zone the dikes have been moved eastward and upward.

PHYSICAL CHARACTERISTICS OF ORE AND INCLOSING ROCKS

There have been two modes of occurrence of ore in both the foot and hanging formations, the more important of which has been the irregularly shaped bodies lying in eastward pitching troughs made by dikes and an impervious member of the formation (see fig. 2). The other may be described as irregularly shaped chimneys of ore following cross faults to great heights above the dikes (see fig. 3).

All ore dips with the formation, which averages about 65°. Dike ore bodies pitch with the dike trough, usually east at 20°. Chimney ore bodies usually pitch westward at 80°. The outlines of all ore bodies are very irregular, due to cross-fault fracture zones and the tendency of the ore to "build up" or concentrate on impervious parts of the formation. Figure 2 shows a typical cross-section of a dike ore body "following up", in impervious footwall and dike.

Cross faults are numerous but do not displace the ore to great extent. Their effect is to increase the irregularity of outline of the ore bodies.

The bedding fault occurred before the formation of the ore bodies but had the same effect as displacing the ore a distance equal to its throw. It has been found that when foot and hanging ore-bearing dikes are in juxtaposition ore occurs from quartzite footwall through the fault zone to the Pence slates.

The bulk of the ore occurs in the Plymouth and Norrie members of the formation. When the Norrie carries ore in full width, the lower part of the Pence and upper part of the Yale members are usually ore bearing.

The ore is medium soft and is drilled generally with auger drills. There are ribs of hard blue ore requiring mounted hammer-type machines. None of the ore is free caving, although it disintegrates rapidly. Narrow ore bodies are considerably firmer than wide ore bodies.

The inclosing rocks of the ore bodies consist of an underlying hard quartzite footwall, and overlying partly leached formations of Plymouth and Norrie members. The formation of these members is similar, consisting of bands of very hard unaltered chert interspersed with bands of softer leached material.

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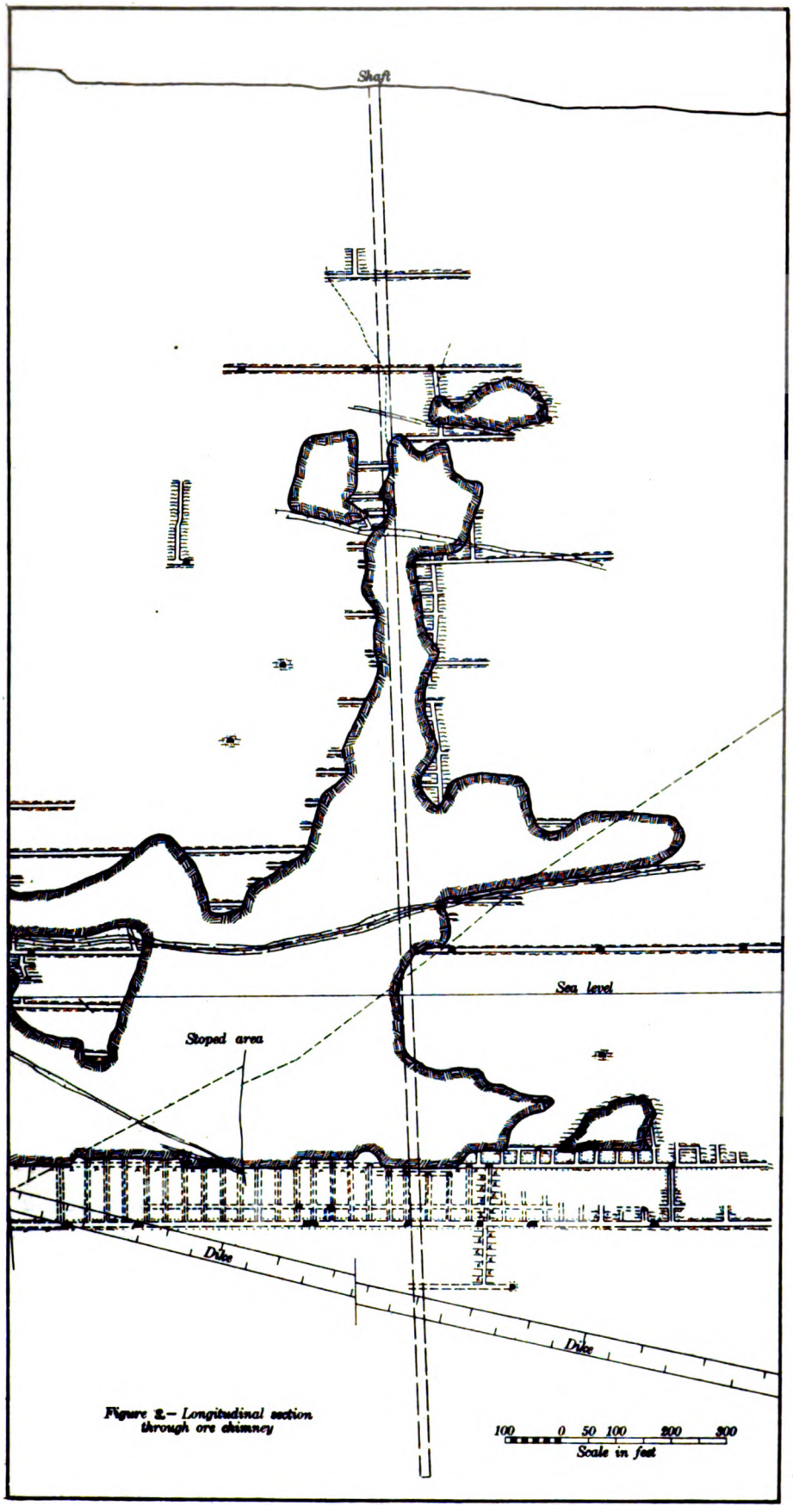

Figure 2.– Longitudinal section through ore chimney

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The bands of leached material form planes of weakness parallel to the bedding. At slightly less than perpendicular to the dip of the bedding cross jointing occurs at regular intervals about 12 inches apart. These jointings form planes of weakness across the bedding.

In the west end of the property the planes of weakness in both directions are much more pronounced than those in the east end, and caving of the "capping" begins soon after the ore is taken out, except in chimneys where area of "capping" exposed, is small. The caved material consists of angular blocks 3 to 24 inches in diameter, a small amount of fines, and few large blocks.

In the east end of the property the bedding is more massive, and the planes of weakness are hardly perceptible. The capping and walls of the ore bodies stand unbroken indefinitely. In places where the ore has been unusually wide or where the capping has been cut off on three sides caving occurs in very large blocks.

To the above conditions two methods of mining have been adapted-sublevel caving where the capping is weak and overhand sublevel stoping where the capping is strong and stands well.

GENERAL ITEMS PECULIAR TO THE DISTRICT

The Gogebic range is a well-established mining center, having many advantages which may be considered ideal.

There is a liberality of thought on the range that encourages the interchange of ideas among the operating companies.

The climate is moderate.

Railroad transportation is excellent. The range is 40 miles from Ashland, a Lake port. The bulk of iron ore from the Lake Superior region is shipped on the Great Lakes to lower lake ports. As navigation is closed during winter it is general practice for underground mines to stock their production for five months of the year.

The industry is on friendly relations with a good class of labor for all branches of mining.

Timber and miscellaneous supplies are near at hand.

Regular equipment generally adopted throughout the Lake Superior iron ore region can be used here.

Electric power is available in plentiful and dependable supply.

Pumping is not a serious problem.

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EXPLORATION

Dikes have been such a controlling factor in the formation of ore bodies that the first step in exploration is the location of the dikes. This is usually done by drifting or crosscutting and by diamond drilling at depth. Diamond drilling is usually done in the Plymouth member for "foot dikes" and Norrie member for "hanging dikes". Holes totaling over 20,000 feet have been put down. It is difficult and expensive work, as the lean formations are vuggy and very abrasive, and richer spots cave readily. The last drilling was a 1,000-foot hole and actually cost the contractor $12.00 per foot.

Dike ore bodies are so regular and continuous that their exact positions may be determined on succeeding levels without exploratory work.

Chimney ore is found by following the quartzite footwall in the foot formation and the upper slates of the Yale member in the hanging formation. These horizons are the most favorable to ore deposition and it seldom happens that ore occurs without showing in these horizons. Practically the whole footwall and favorable territory in the hanging have been explored at intervals of 200 feet along the dip. Unproductive parts of the hanging are explored at regular intervals by crosscuts from the foot drifts.

Fig. 4. METHODS OF SAMPLING AND ESTIMATION OF TONNAGES

	MONTREAL Per cent	HAMILTON Per cent	ONTARIO Per cent
Iron	60.50	60.05	54.50
Phosphorus	.045	.065	.070
Silica	7.80	8.20	8.60
Manganese	.40	.50	5.00
Alumina	2.00	1.65	1.40
Lime	.30	.30	.32
Magnesia	.15	.15	.16
Sulphur	.008	.008	.010
Loss by ignition	3.10	3.46	4.70
Moisture	-	-	-
Combined Fe & Mn	-	-	59.50

Figure 4 gives the analysis of the different grades of ore mined.

Standard methods of sampling and preparing samples tending to eliminate the judgment of the sampler, are in use on the property. (See Figs. 5 to 11).

In the development of an ore body, the ore is blocked out so that enough trench samples may be taken across the formation to allow accurate estimate of the analyses of the ore in place. Tonnage in dike ore bodies is calculated by regular prism formula.

The straight iron ores are graded on phosphorus and silica; the manganiferous ores on manganese and silica. The iron is usually acceptable as to grade in all ores if the silica is controlled.

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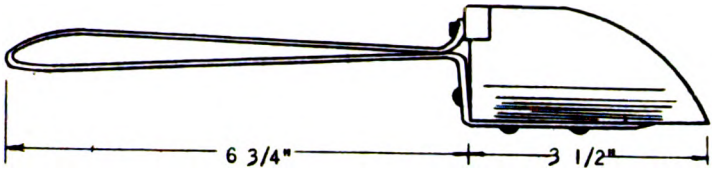
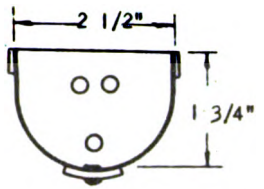
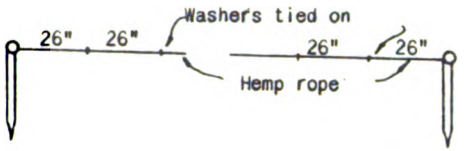


Plan



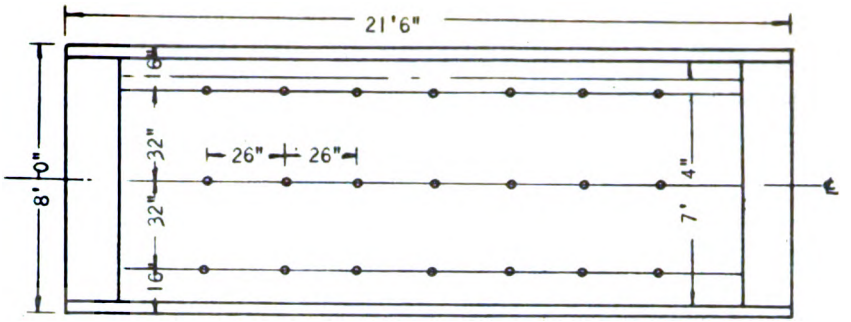
Front view

A

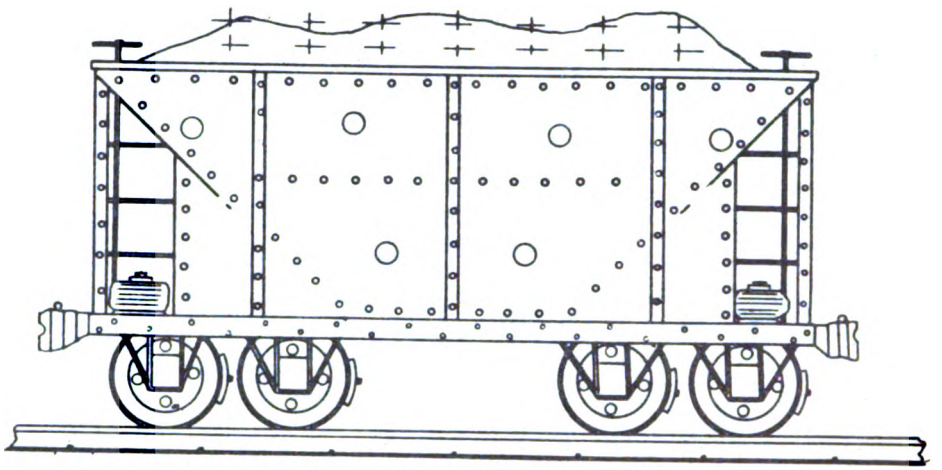


B

Figure 5.- A, Standard sampling scoop; B, standard sampling line for steel ore cars



Plan



Elevation

Figure 6.- Standard ore car sampling

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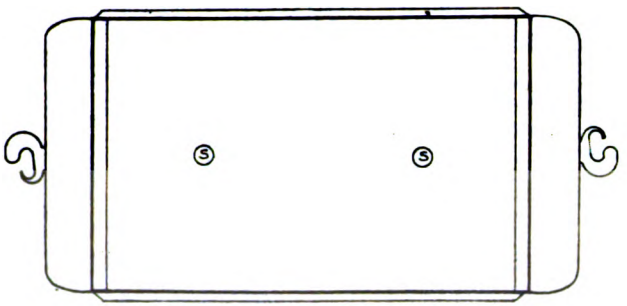
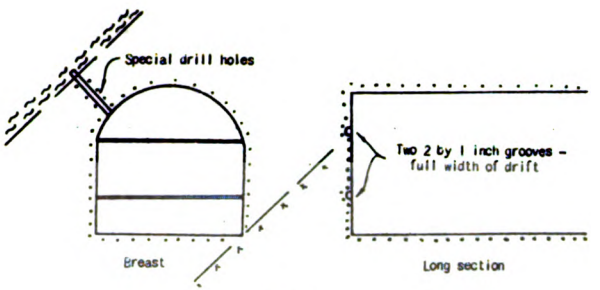
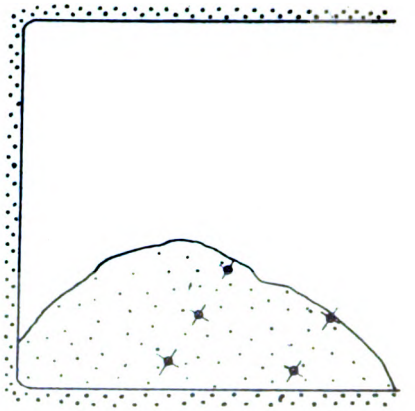


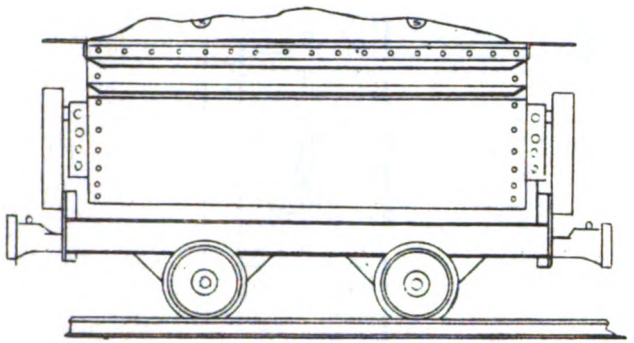
Plan



DRIFT

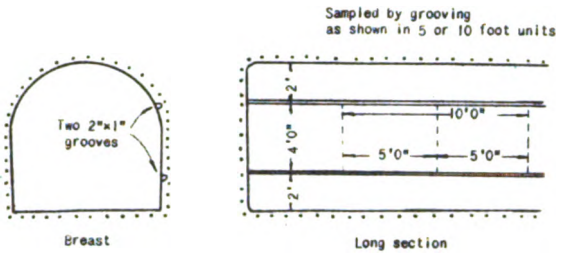


Long section



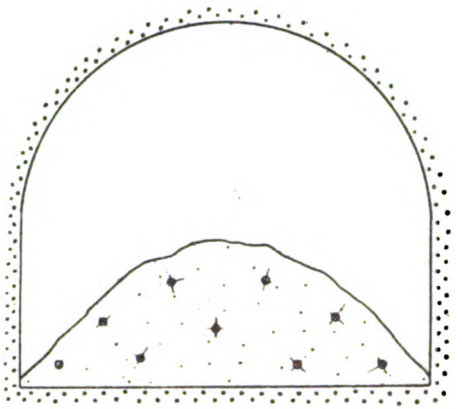
Elevation

Figure 7.- Underground car sampling



CROSSCUT

Figure 8.- Special underground samples



Cross section

Figure 9.- Underground sampling

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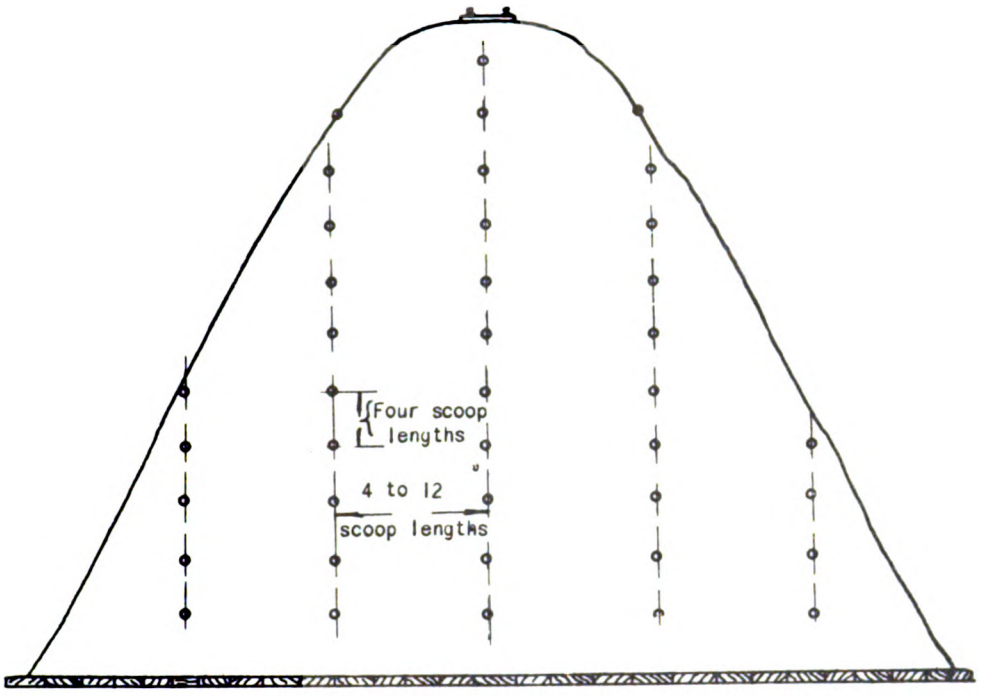

Figure 10.- Stockpile sampling

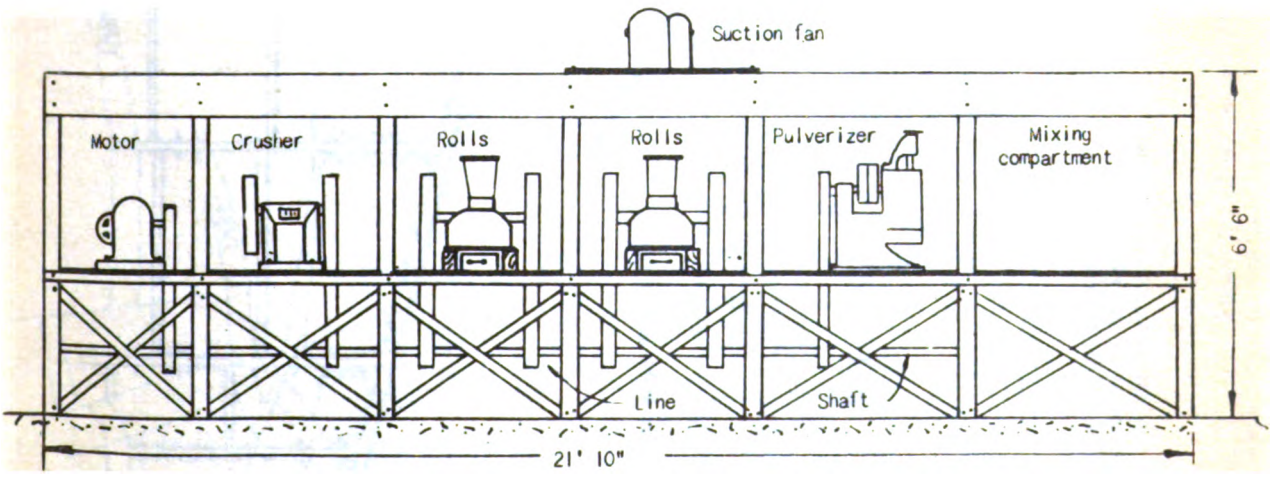

Figure 11.- Crushing plant

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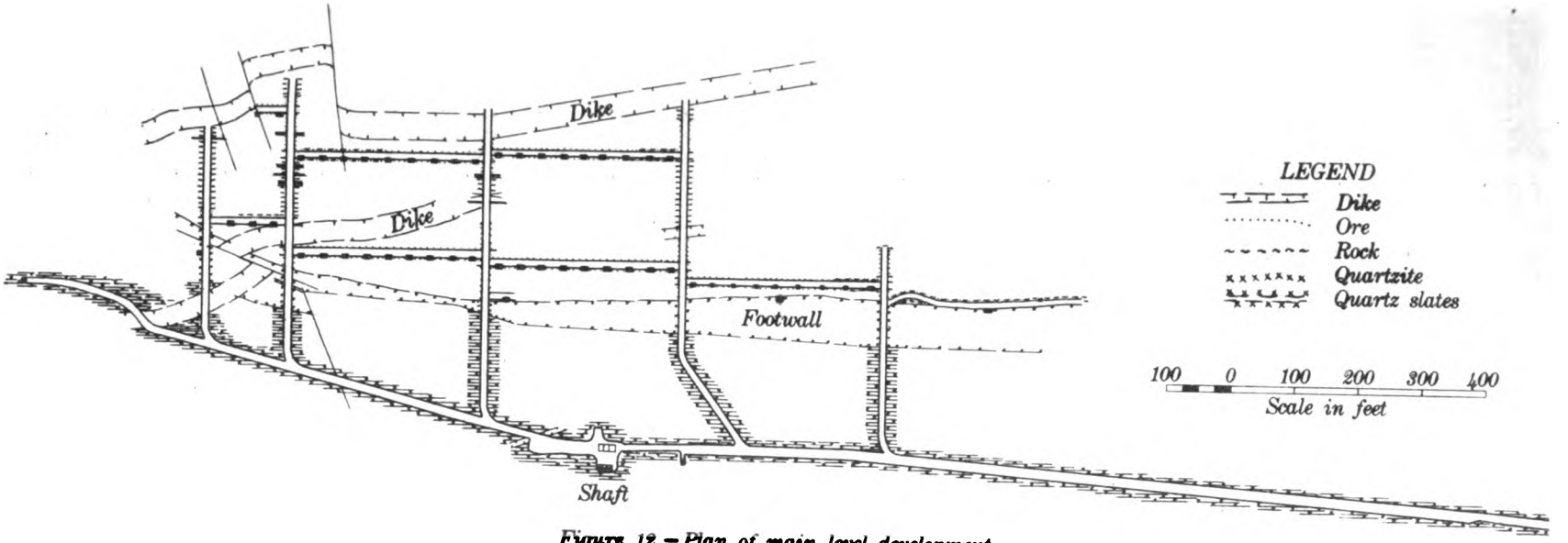

Figure 12.—Plan of main level development

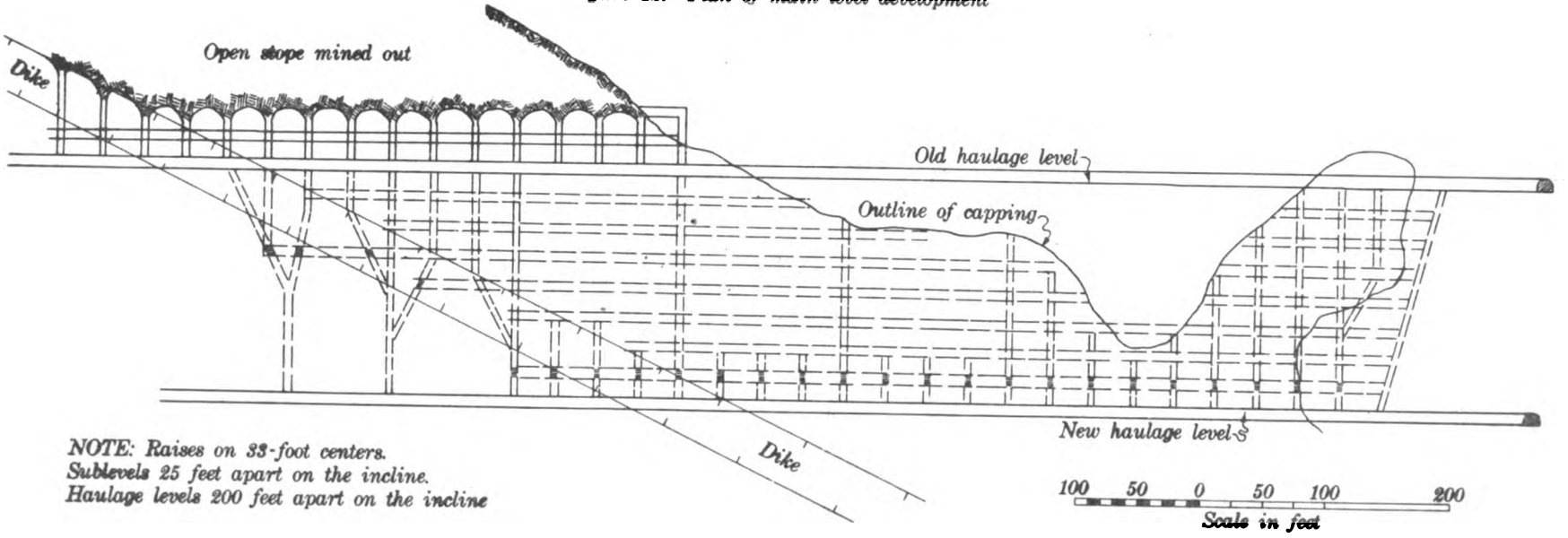
Open stope mined out
Dike
Old haulage level
Outline of capping
New haulage level
Dike
NOTE: Raises on 33-foot centers.
Sublevels 25 feet apart on the incline.
Haulage levels 200 feet apart on the incline
100 50 0 50 100 200
Scale in feet

Figure 13.—Longitudinal projection on a vertical plane. East end ore body with hard walls

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The underground sampling for the control of phosphorus and manganese is done on the ore in place, with grab samples as a check.

The underground sampling for the control of silica is done by grab samples of the broken dirt in the working place.

Control samples are checked by tram-car samples.

Ore is stocked in winter according to underground control samples, but check samples of the stockpile are taken and located to assist in the grading, in shipping season.

The ore is shipped to the lake dock in 50-ton cars. The tonnage of lake cargoes ranges to a maximum of 14,000 tons.

Grading is governed in shipping direct, and from stockpile by samples of railroad cars in 5-car lots.

Due to the variation in analyses of ore that must enter one grade, provision is made at the shipping dock to average the analyses. This is done by selection of the last railroad car to complete a 6-car loading pocket.

Samples are prepared and analyzed on the property. A 10,000-ton cargo is represented by 40 samples, weighing 2,400 pounds, taken at 4,800 points on railroad cars.

METHODS OF DEVELOPMENT

During the last few years there have been three shafts in operation on the property, two inclined approximately paralleling the dip and one vertical. An attempt has been made to make the level interval suit the conditions. At one shaft with comparatively large ore bodies close to the shaft the level interval is 125 feet along the dip. For small ore bodies close to the shaft, the level interval has been 200 feet along the dip. For small ore bodies remote from the shaft the level interval has been 300 feet.

In the deeper territory, which is to be served by one shaft, the level interval has been set at 165 feet along the dip.

As the position of the larger dike ore bodies is known, crosscuts from the shaft are directed to shorten transportation from them. These crosscuts are either double track or single with passing track.

Two plans of development are used to open up the ore bodies on the property:

A. Development for wide ore bodies where the sublevel caving method of mining is used (fig. 12).

B. Development for narrow ore bodies where overhand sublevel method of open stoping is used (fig. 13).

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Development is simplified by the fact that the position and general outline of the larger ore bodies are definitely known before they are attacked. It is also of great advantage, with the smaller ore bodies, to have the exploratory drifts by which they are located always on the foot side, the correct position for development.

DEVELOPMENT DETAILS

Shafts - See Figures 14 and 15.

There are three shafts on the property, two inclined in the slates, one vertical in the greenstone (diorite). The inclined shafts are located at 4,600 and 10,000 feet from the west property line; the vertical shaft is between, at 7,000 feet.

The three shafts are similar in design (see fig. 16). All have five compartments, to accommodate one cage, two skips, pipes and cables, and a ladder road. In one inclined shaft, the skip roads are on the footwall plates, with the pipe and ladder ways over head. In the other inclined shaft, the skip roads are on a subdivider with pipe and ladder ways underneath.

The vertical shaft is lined with 6-inch H steel, 7-foot centers, without lath; the greenstone walls are gunited. The skiproads are inclosed with precast concrete lath. The inclined shafts are lined with 6-inch H steel, 5-foot centers, and 3-inch tamarack plank in one, and precast concrete lath in the other.

Cages - See Figure 17.

Cages in the three shafts are double deck, 36 to 40 men are handled per trip, and provision is made to handle material on both decks. The cage in the vertical shaft is fitted with chairs attached to the bottom and operated from the inside of the cage. All cages have safety catches.

Skips See Figures 18 and 19.

Skips are self dumping, generally known as the Kimberly type. Skips in the vertical shaft are fitted with safety guides to prevent boxes from tipping in the shaft. The skips in the inclined shafts have capacity of 5 long tons; skips in vertical shafts hold 8 long tons. Chairs are used in loading the skips.

Hoisting and Stocking - See Figures 20, 21, and 22.

Cages are hoisted unbalanced in inclined shafts. In vertical shaft, cage is balanced by sectional cast-iron counter-weight running in 12-inch pipe. In unbalanced cage hoisting, single-drum hoists are used. In the vertical shaft, the hoist for balanced cage is a duplicate of the skip hoist, and may be used for replacement in case of breakdown, as there are two other cages in operation. Hoisting speeds for cages are 750 and 1,000 feet per minute. Hoisting speeds for skips are 1,200, 2,000, and 2,500 feet per minute. Both cage and skip hoists are equipped with speed control and overwind-prevention devices.

Skips are operated in balance.

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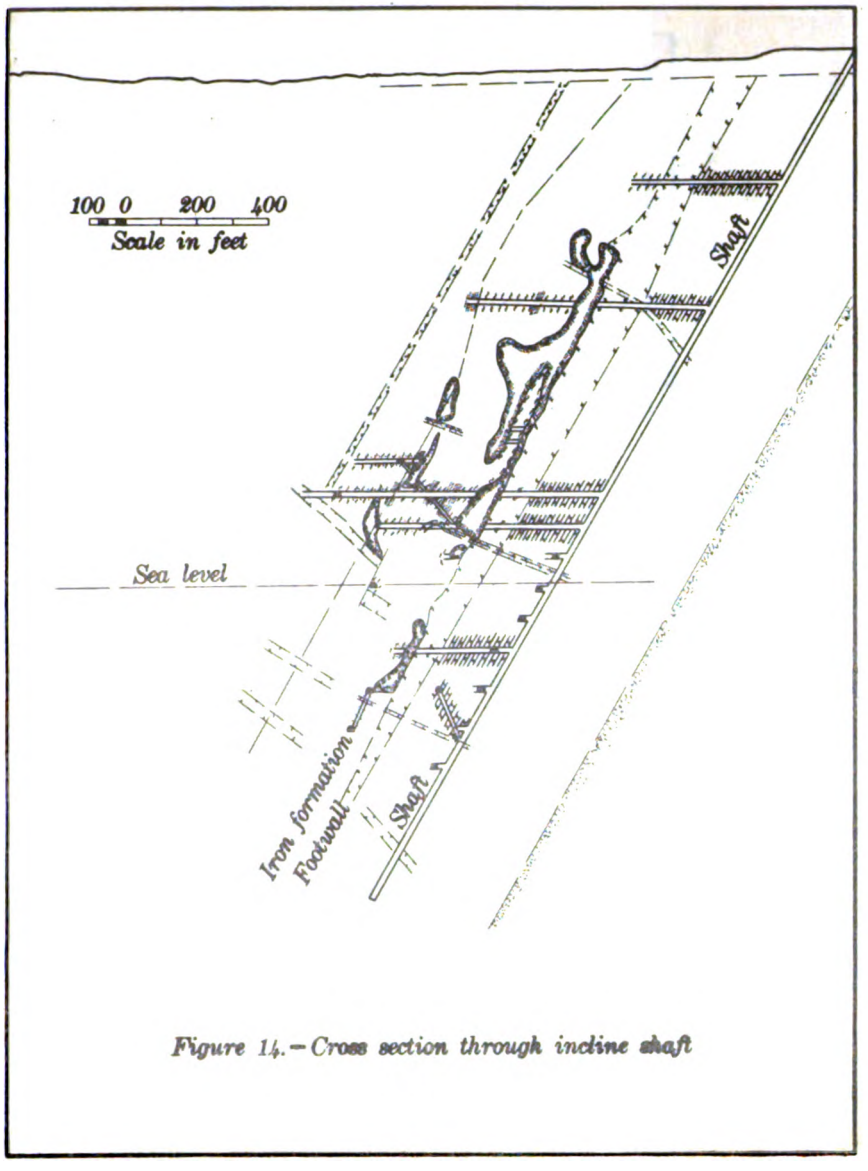

Figure 14.—Cross section through incline shaft

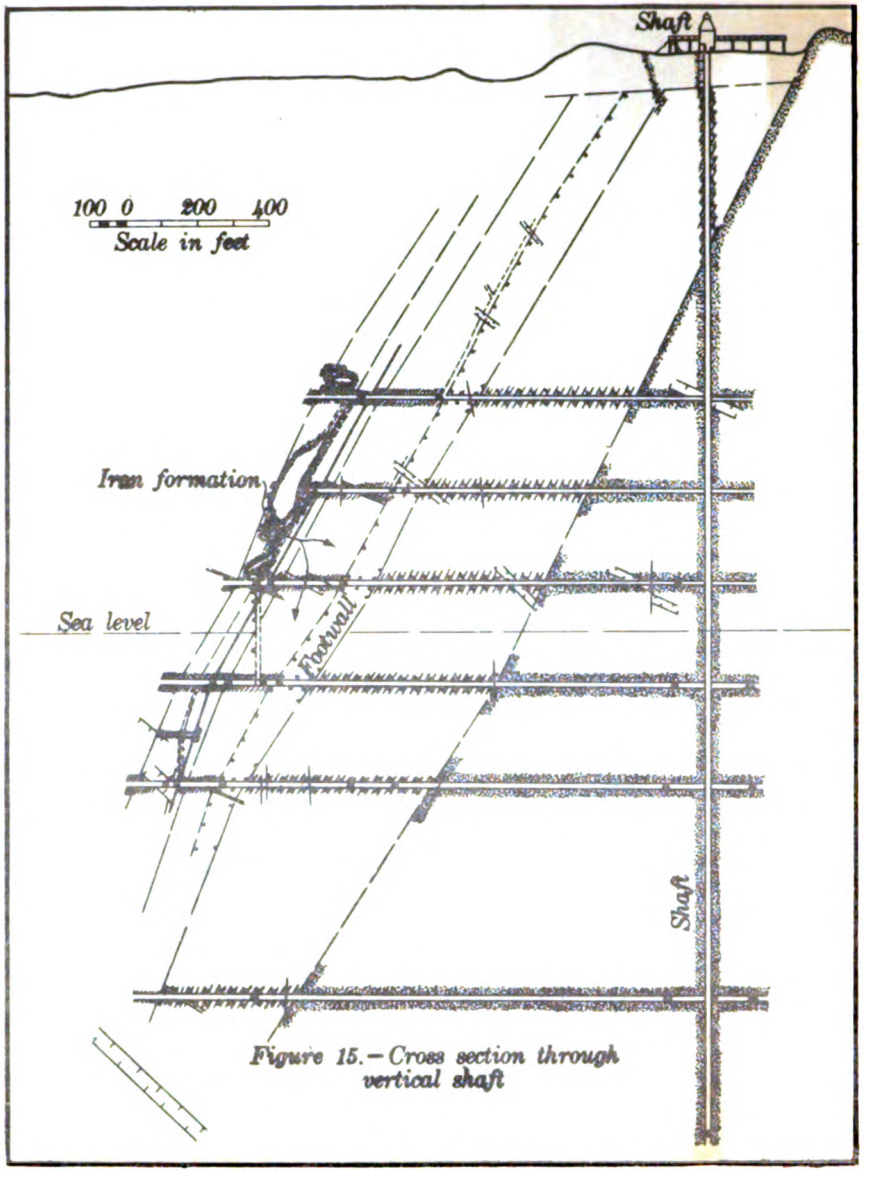

Figure 15.—Cross section through vertical shaft

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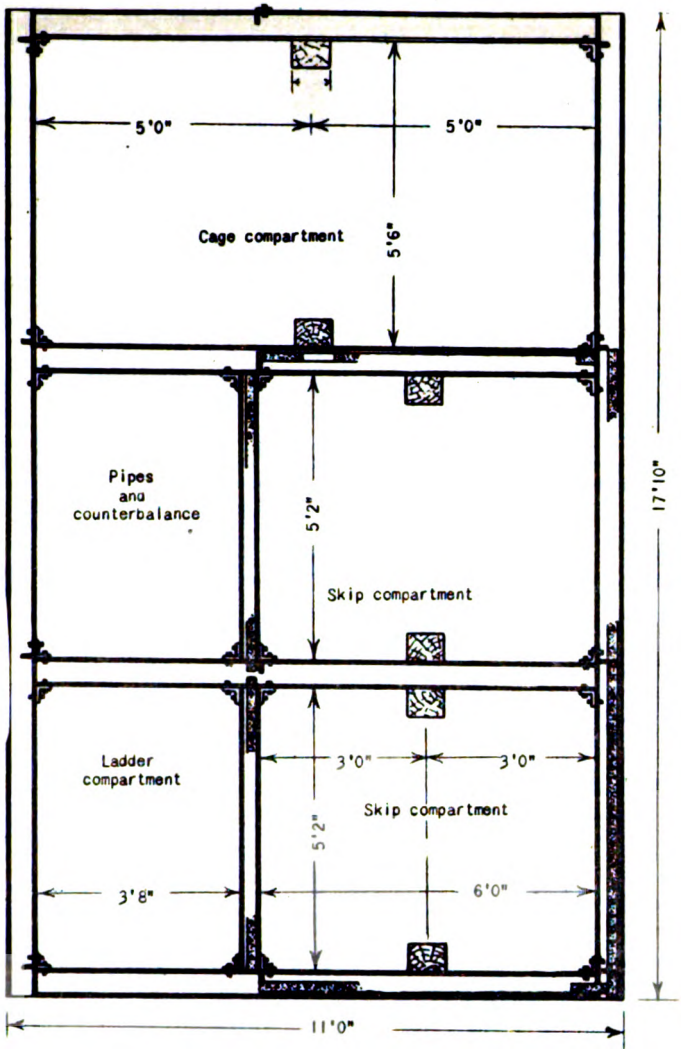

Figure 16.- Steel shaft liner sets

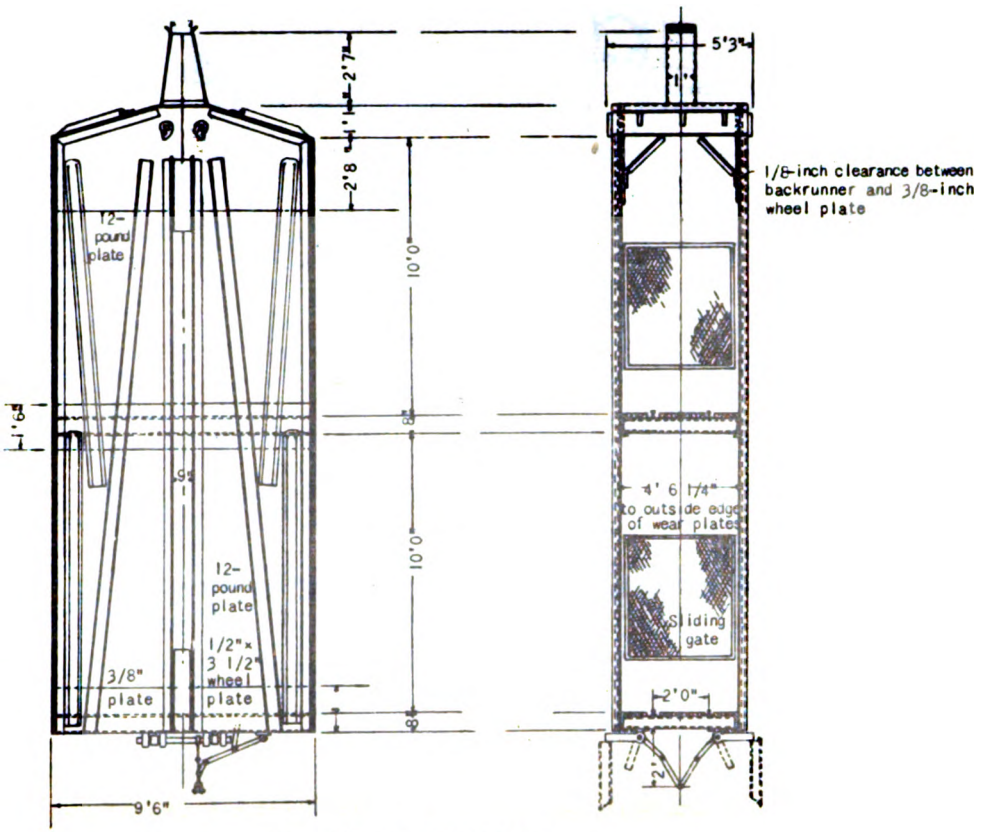

Figure 17.- No. 5 shaft cage

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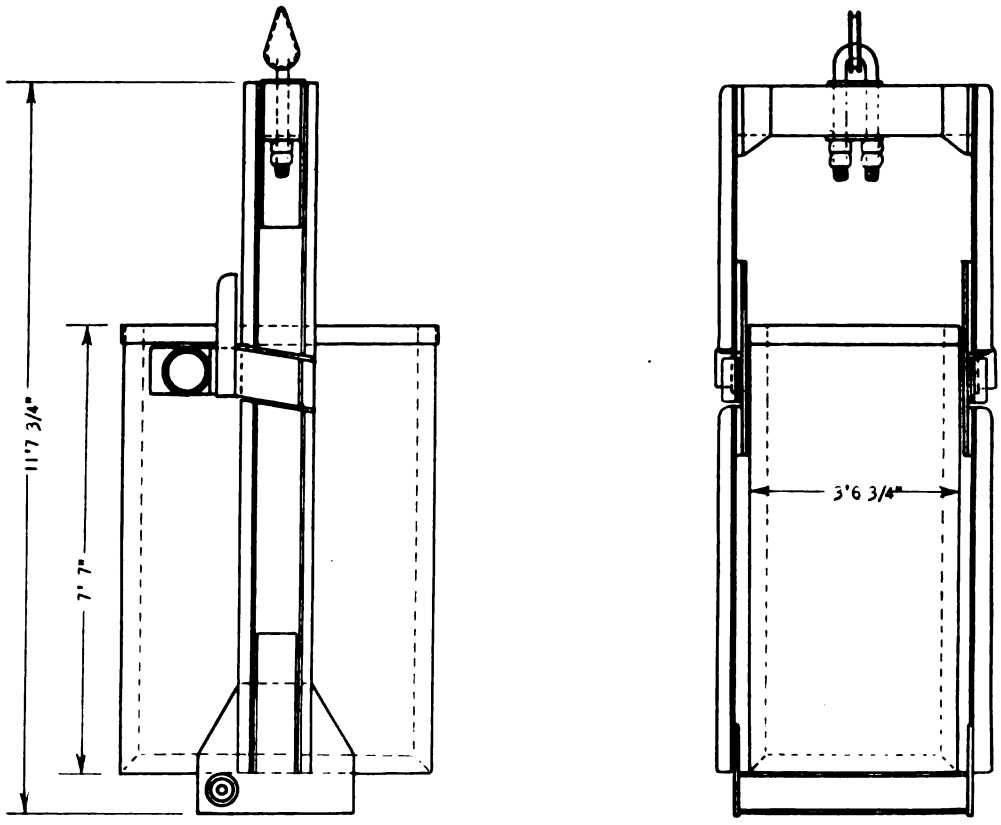

Figure 18.- Skip, vertical shaft

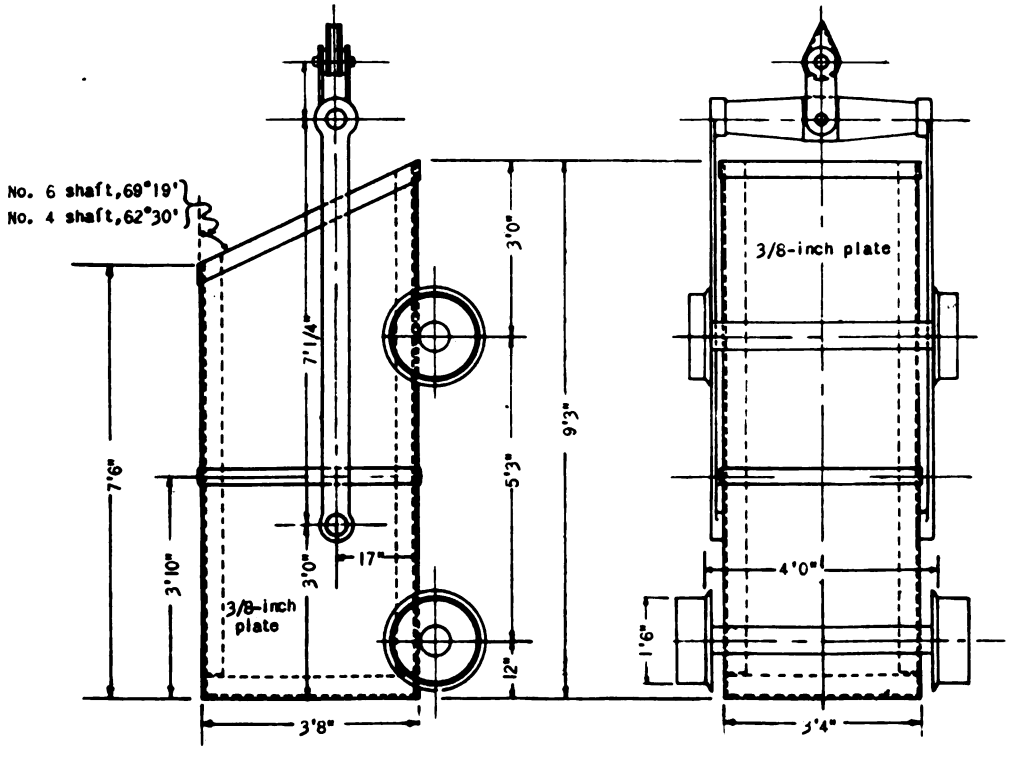

Figure 19.- No. 6 shaft skip

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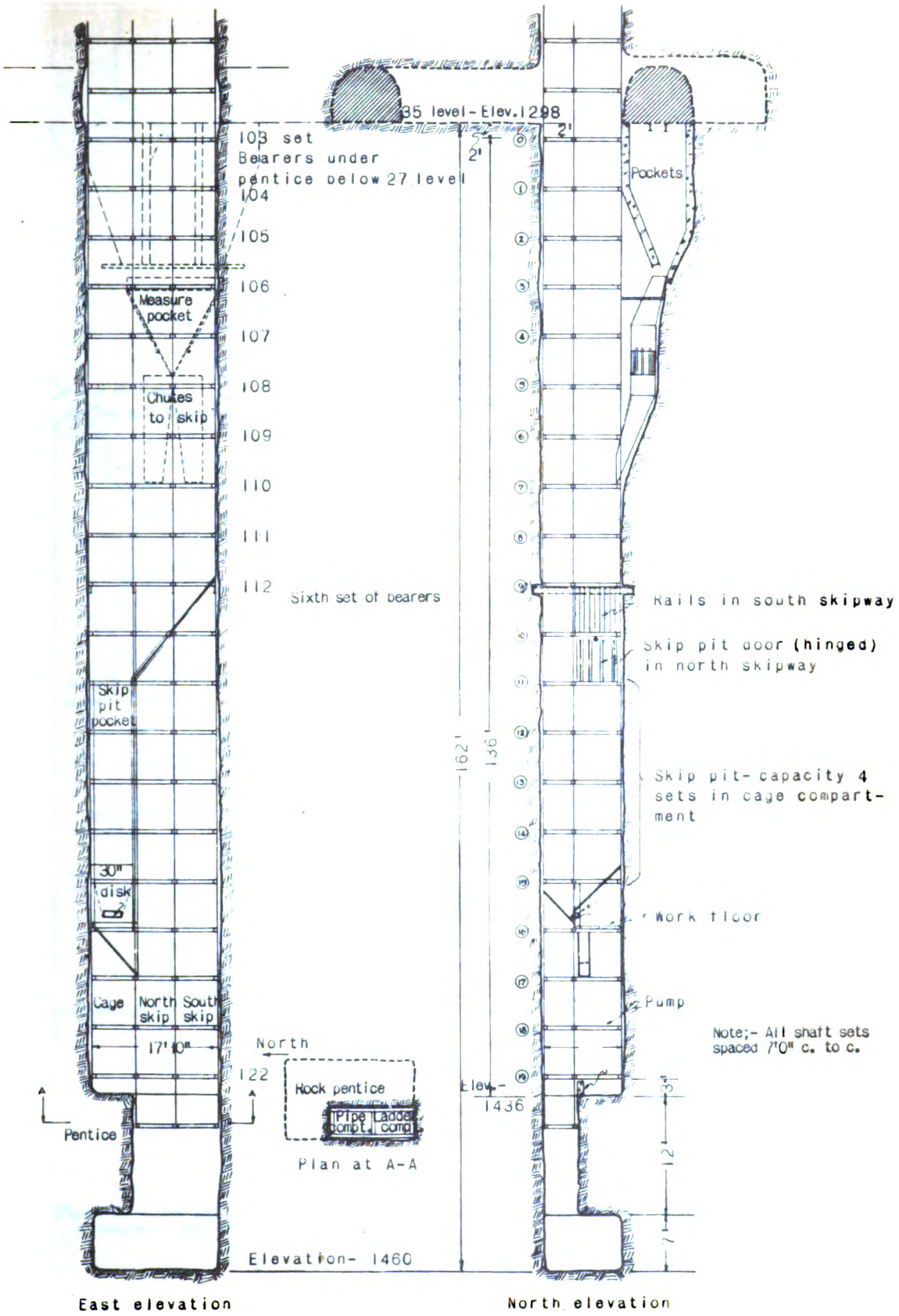

Figure 20.- Shaft layout below 35 level, No. 5 shaft

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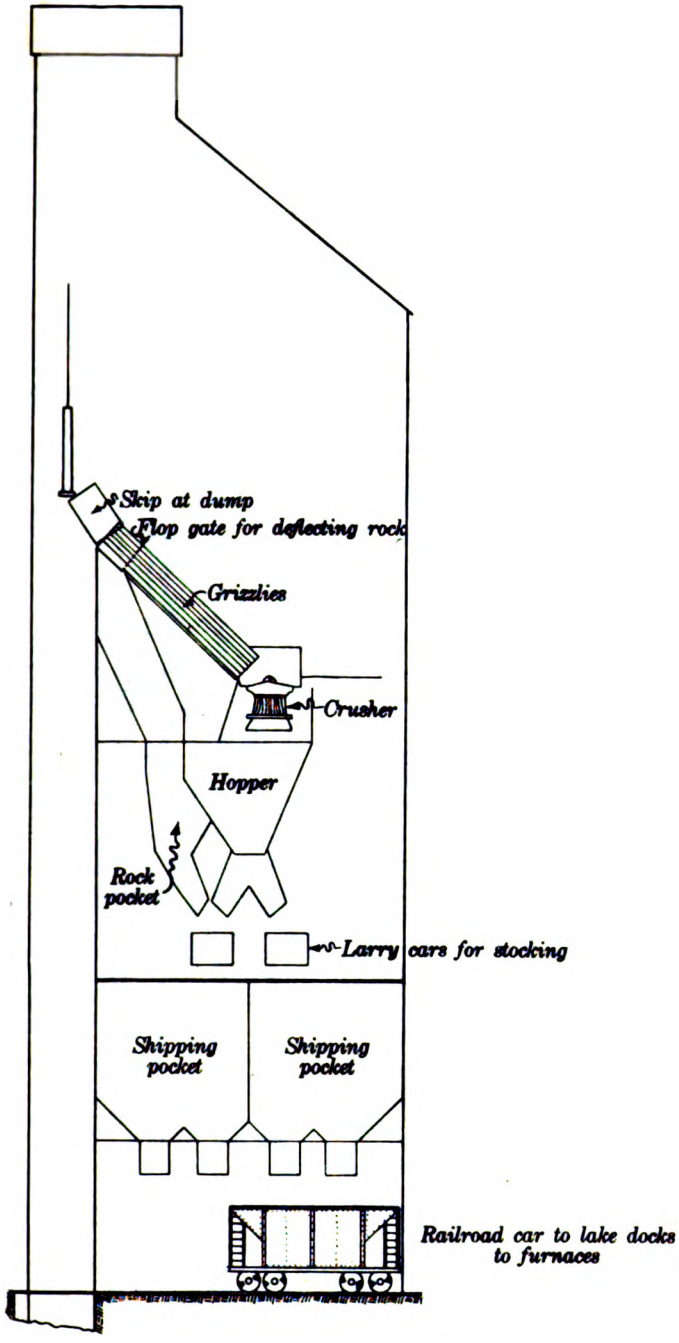

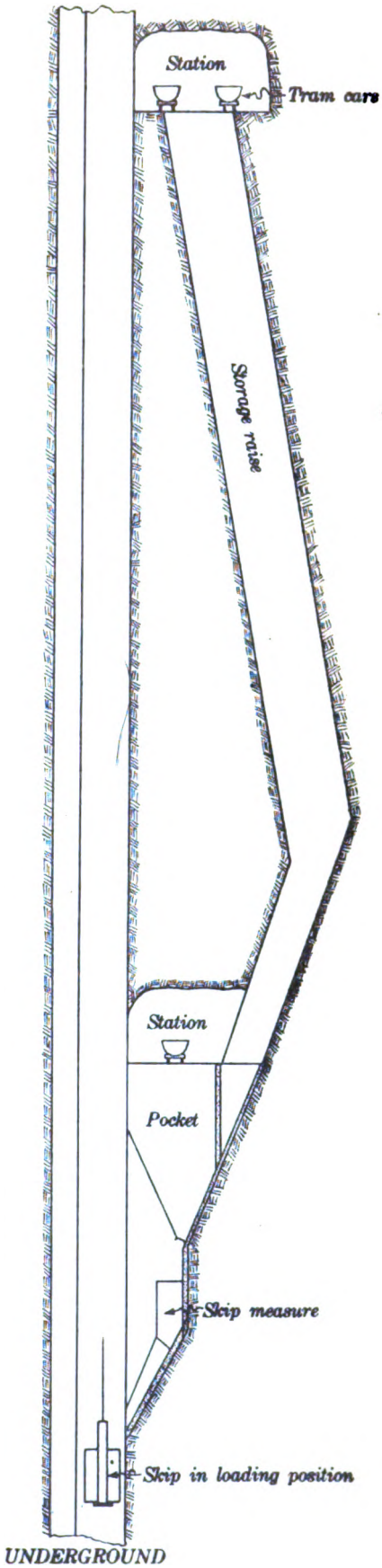

Figure 21. – Flow sheet showing course of ore from underground stations to surface railroad cars

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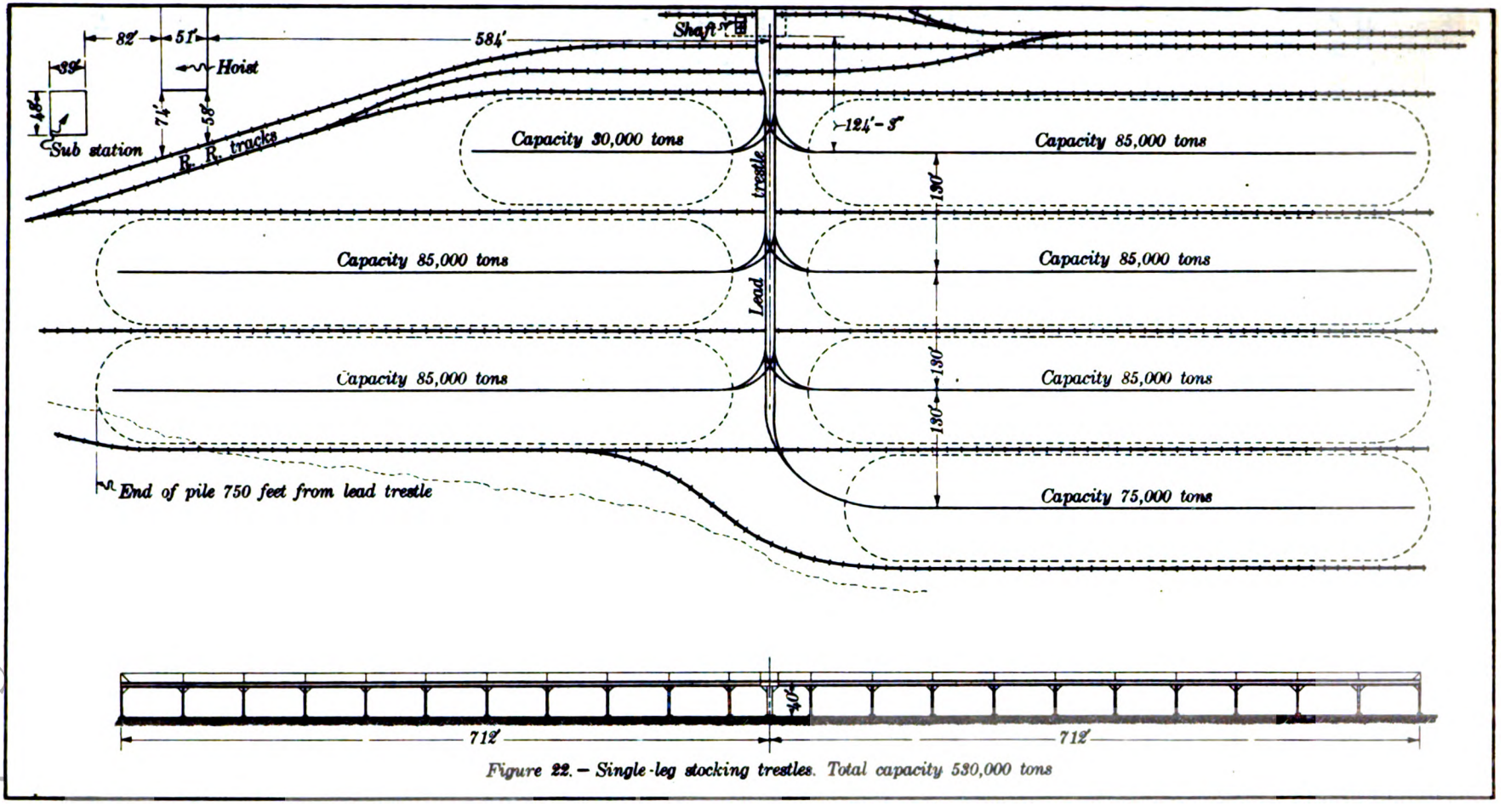

Figure **22.** — ***Single-leg stocking trestles.*** *Total capacity 530,000 tons*

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For rope capacity, the practice is to use 10 foot diameter drums with one overlap.

In skip hoisting, double drum and double clutch hoists are used, which allow both drums to work free on the shaft.

1 1/4-inch and 1 3/8-inch regular lay ropes, with independent steel center, are used. Lang lay rope is used for overlapping at high speed. Non-spinning rope is used on counterweight.

Spillage is deflected from both skip compartments to a pocket in cage compartment. A hinged door allows one skip to go through for hoisting.

Hoist drives are geared-induction motors, first motion steam and direct-connected direct-current motor. The direct current motor is 2300 hp., driven by a 2000-kw. synchronous motor-generator set.

Ore hoisting at the two inclined shafts will be discontinued at an early date. The vertical shaft equipment is designed to handle four grades, totaling 1,000,000 tons per year.

For stocking total production at vertical shaft 16-ton lorry cars, with remote control, and single-leg permanent trestle are installed.

Compressed Air

Compressed air is furnished by three 2-stage compressors with after coolers; capacity of compressors is 7,000 cubic feet free air per minute to 100 pounds pressure. Air is conveyed underground through a 6-inch pipe in each shaft. A 6-inch line on surface connects receivers at each shaft. Four-inch lines are taken off from main line at the levels. Pressure at working faces is 90 to 95 pounds. The distribution is sectionalized by valves. A man at each shaft is held responsible for shutting off all valves between shifts, except those left open by request.

Water Supply

Water for drinking is piped from city mains. To avoid high pressure constant flow is maintained with break in lines on intermediate levels. Water for drilling, etc., is piped from underground sources, reducing valves being used.

Lighting

Shaft stations, pockets, timber stations, and pump houses are brightly lighted. Main levels are lighted with 50-watt lamps at 40 foot intervals. On the sublevels of the sublevel caving method there is a 50-watt lamp at the top of each raise being used. Working faces are lighted by lamp and protective reflector on extension cord.

Alternating current is replacing direct current for lighting.

Two-hour carbide lamps are in general use. The company furnishes carbide.

Power

Electric power is used throughout the property for all work except hoisting ore at one shaft. It is brought to the property by a commercial power company from two independent sources, over 33,000-volt lines. It is delivered to the mining company at 2,300 volts. All large motors on the property take power at 2,300 volts.

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Direct current is supplied by two motor-generator sets on surface, and two rotary converters underground. Automatic reclosing circuit breakers are used on D. C. feeders.

Drilling Equipment

Several rock-drill manufacturers compete in the field, and they are depended upon to develop equipment adapted to the conditions.

At the present time the following drilling equipment is available for use.

35 - 4-inch water-hammer drills for main level development in greenstone and hard lean formation rock.

9 - 3½-inch water hammer drills for main level development in medium hard formation and slates.

6 - 3-inch rock drills for use in hard ore development.

21 - hand-rotated stoping machines, both wet and dry, for rock and hard ore raising.

8 - 55-pound sinking water-hammer machines for slates.

103 - 40-pound auger drilling machines for development and mining in ore.

All machines are equipped with line oilers.

Regular practice is to use two machines in all working places, except raises and double-track crosscuts. Rock drills are mounted on posts with arms. Auger machines are unmounted, one quarter of them are equipped with detachable feed legs (see fig. 23). In double-trach crosscuts six machines, mounted on a drill carriage, are used (see fig. 24).

One and one quarter-inch round hollow drill steel, with lugged shank and double taper (5 - 14 degrees) cross bit, made up in 10-inch runs with 1/8 inch difference in gauge, is used for rock drilling. All drills bottom with 1½-inch hole. Auger steel and 7/8-inch quarter octagon hollow steel with square shanks and collars are used in auger machines. Seven eighths-inch hollow and 1-inch solid hexagon steel with hexagon shanks and collars are used in sinkers and stopers.

Daily, 1,100 to 1,200 pieces of steel are sharpened to supply the machines in operation. About 40 tons of drill steel are in use, and the annual consumption averages 40 tons, or 0.075 pound per ton ore mined.

Mucking Equipment.

All mucking is done with scraper and double drum, 250-volt, D. C. electric slusher hoists. The number of units in operation depends upon the proportion of ore mined by open stoping and sublevel caving.

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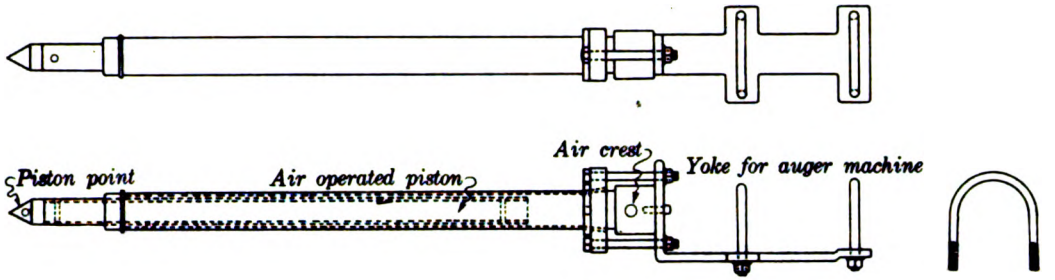
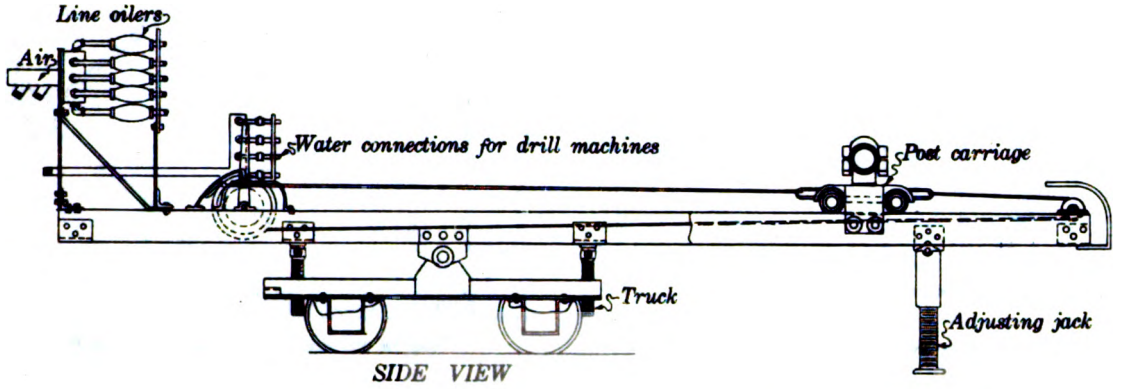


Figure 23. – Detachable feed leg for auger drill machine



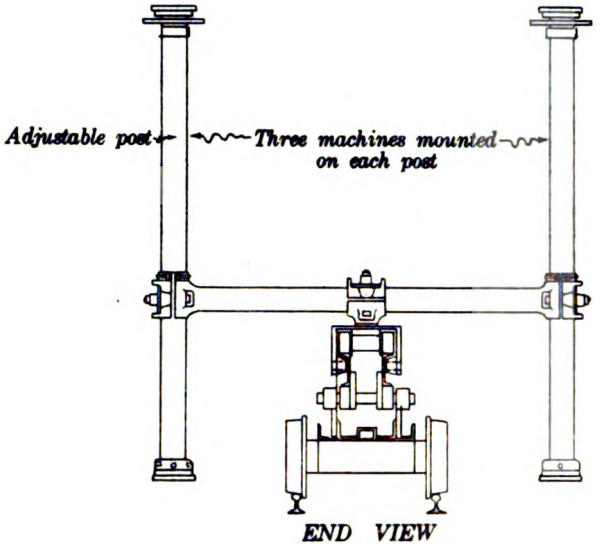


Figure 24. – Drill carriage

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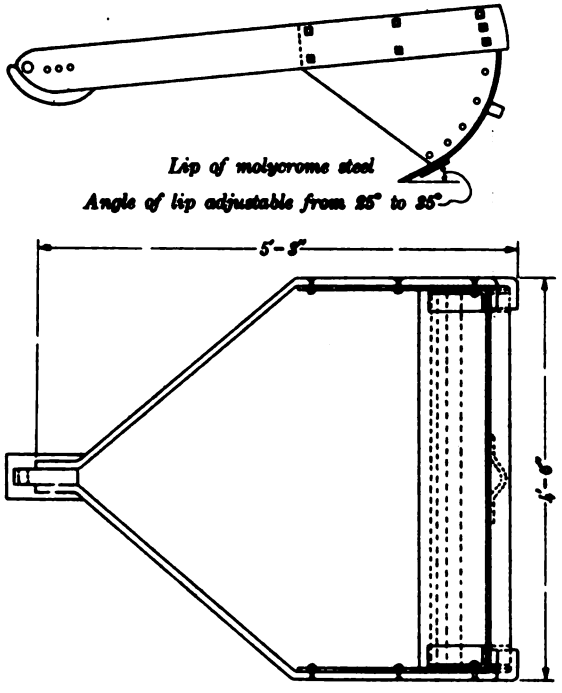

Figure 25. — 54-inch hoe-type ore scraper

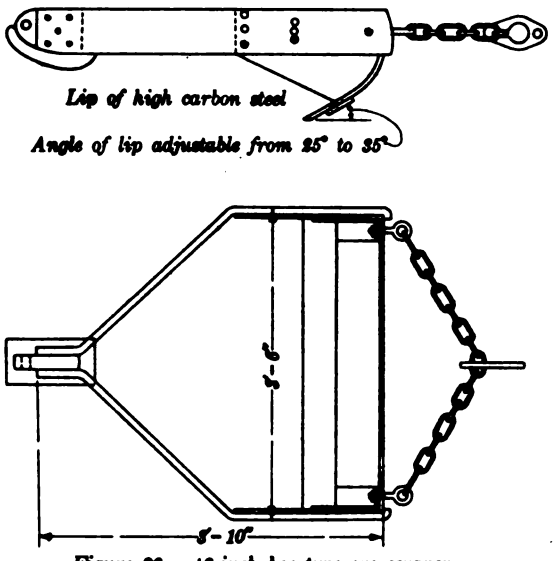

Figure 26. — 42-inch hoe-type ore scraper

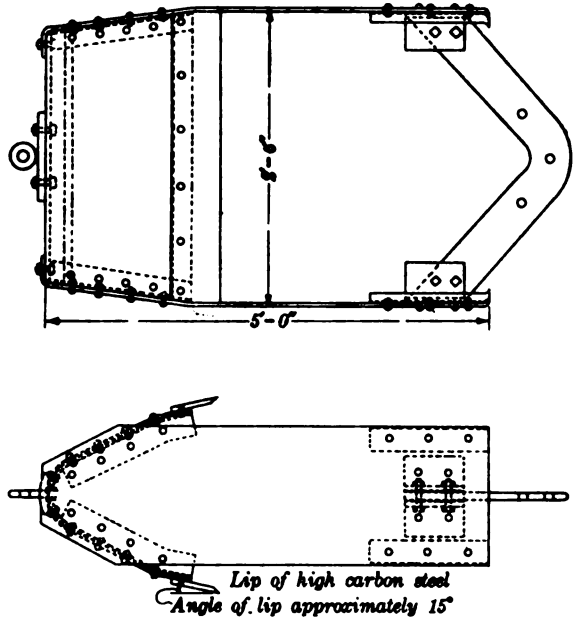

Figure 27. — 30-inch box-type ore scraper

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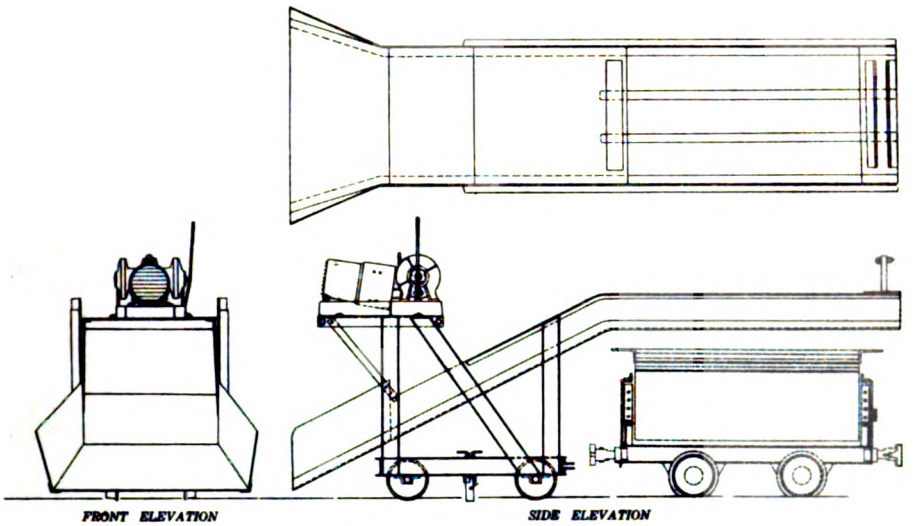
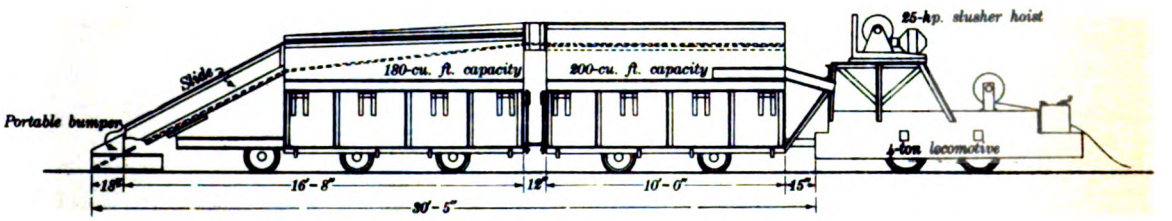
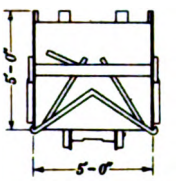


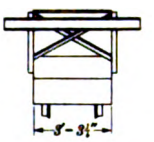
Figure 28. – Underground slusher slide



SIDE ELEVATION

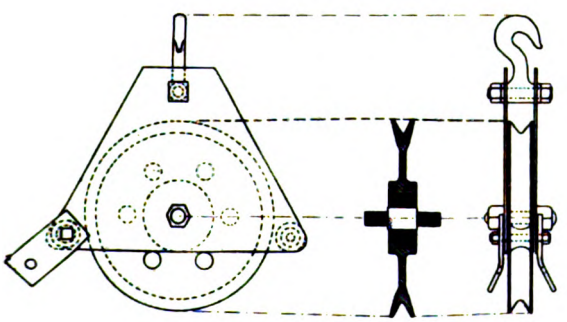


FRONT ELEVATION

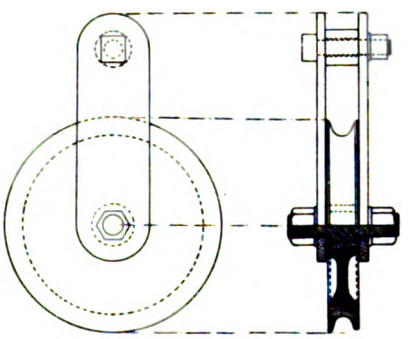


REAR ELEVATION

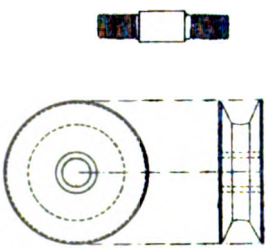
Figure 29. – Underground car unit with slide and motor, used in driving double track crosscuts



16-INCH DIAMETER



7-INCH DIAMETER



4-INCH DIAMETER

Figure 30. – Cast-steel sheaves used with 25-hp. slusher hoists

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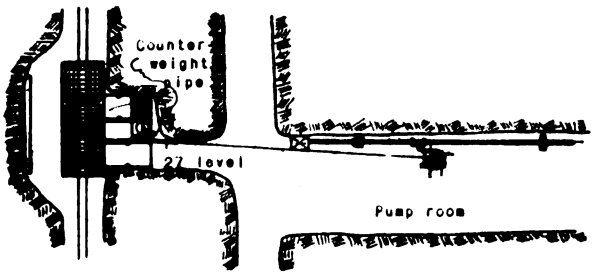
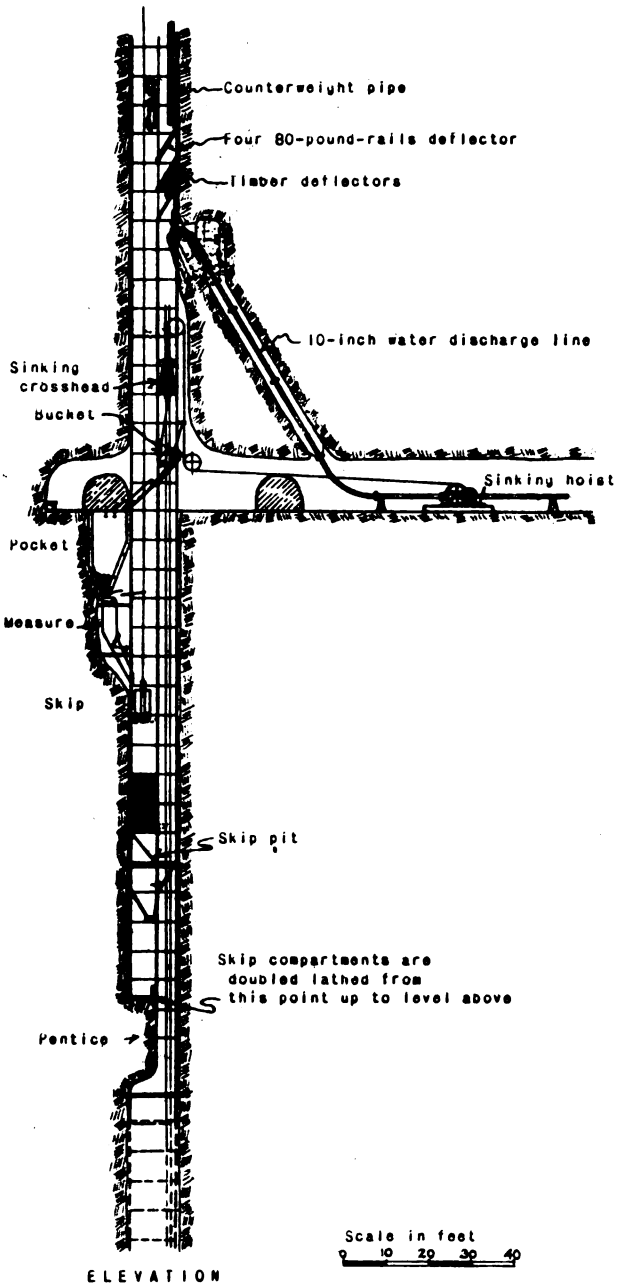


PLAN



ELEVATION

Figure 31.- Sinking arrangement below 27 level, No. 5 shaft

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The following equipment is available:

12 - 25-hp. hoists with 54-inch hoe-type scrapers (see fig. 25).

29 - 15-hp. hoists and 42-inch hoe-type, or 30-inch round-back box-type scrapers (see fig. 26).

15 - 10-hp. hoists and 30-inch round-back box-type scrapers (fig. 27).

24 - 7½-hp. hoists and 30-inch (V-back box-type scrapers.

10 - portable car-loading slides (see fig. 28).

1 - 380-cu. ft. car unit with slide (see fig. 29).

The 25-hp. hoists are used in loading cars. The other hoists are used in development and mining. Repairs on 7½-hp. hoists are excessive; they are being replaced by 15-hp. hoists.

The portable car-loading slide is used for single-track drifts and crosscuts. The 380-cubic foot car and slide is used for double track crosscut in greenstone.

Sixteen-inch cast-steel sheaves with ball bearings are used with 25-hp. hoists (see fig. 30). Ten-inch cast-steel sheaves with ball bearings are used on loading slides. Seven-inch cast-iron sheaves with graphite bronze bushing are used in mining. Cheaper construction is used on mining sheaves on account of loss. Six-inch cast steel with bronze graphite bushing is used for idler sheaves.

Shaft Sinking - See Figure 31.

Shaft sinking is carried on under a pentice while the shaft is operating. The practice is to sink several hundred feet for each set-up of equipment. The last sink in an inclined shaft was 625 feet, in the vertical shaft 850 feet.

Sinking equipment consists of a geared single-drum electric hoist with clutch for fast lowering. Cage or carriage and bucket are fitted with safety catches to prevent dropping in case rope breaks and guards to prevent bucket leaving cage or carriage.

Two 20-cubic foot buckets are used in hoisting rock. Three-quarter-inch and 1-inch ropes are attached to buckets with sockets, U strap, and safety pin.

Materials are handled in buckets. Men ride on cage in vertical shaft sinking, in the bucket in inclined shaft sinking.

In vertical shaft sinking buckets are dumped into hinged chute, which covers hoisting compartment when in dumping position. In inclined shaft sinking bucket is lowered from carriage and clears shaft to dump.

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For sinking in quartz slates, eight 55-pound water-hammer drills are used with 7/8-inch hollow hexagon steel. For sinking in greenstone, four 4-inch and four 3½-inch mounted water drills are used with 1¼-inch round lugged steel. The 4-inch machines are required in hard, "fitchery" spots. Air and water manifolds are used. A line oiler is placed on the air hose of each machine.

Blasting is done with 60 per cent gelatin powder, tamped with clay, and fired with electric delay igniters in parallel. (See fig. 32). Current of 220 volts, A. C., and 250 volts, D. C. are used. In inclined shaft sinking Blasting line is reeled down for each blast. Shaft bottom is blasted in two rounds (see fig. 33). Mucking is done by hand with No. 3 long-handled shovels directly into the bucket.

The steel sets are put in as follows: - End pieces and wall plates of a set are hung after second blast of each cut. In hanging the squares end pieces are lowered to bottom, studdle is bolted on, and it is then raised into place with block and line; a man (with safety belt) sits on the last set and guides the piece into place and catches it up with bolt. After several squares are hung in this manner staging is used to put in dividers and line sets and is wedged with cement sacks filled with concrete. Staging consists of four-30-pound rails, which are hung by short hangers to the set being wedged, and covered with loose plank 7 feet long.

Bearers of 12-inch I-beam steel are put under dividers and end pieces at 145-foot intervals.

Ventilation is furnished by 15-hp. reversible fan with 16-inch galvanized iron pipe with stove-pipe joints.

Shaft work is carried on in 8-hour shifts, three shifts per day. Crew consists of eight men and boss in bottom, brakeman, and lander on top. Average advance is over 100 feet per month.

The greenstone is a hard, dense, igneous rock. The average penetration with heavy water-hammer drills is 5 inches per minute; it is generally uniform and free drilling. The quartz slates are medium hard. The average penetration with medium weight water-hammer machines is 12 inches per minute. They are uniform and free drilling. Both rocks break well and stand well. It is not necessary to keep lining close to the bottom of shaft. Greenstone breaks coarse, slate rock fine. No water is encountered in shaft sinking. The water from drilling and leakage from above are hoisted in sinking bucket.

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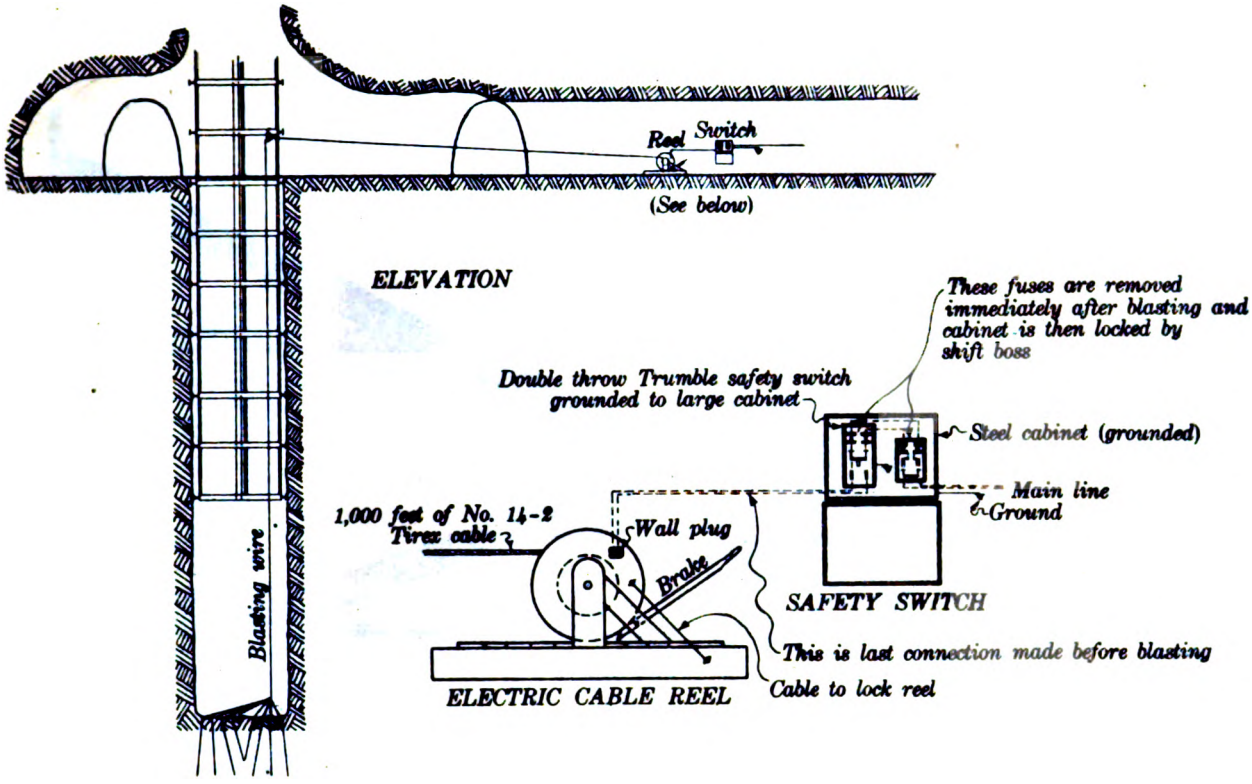

Figure 32.—Shaft sinking blasting arrangement

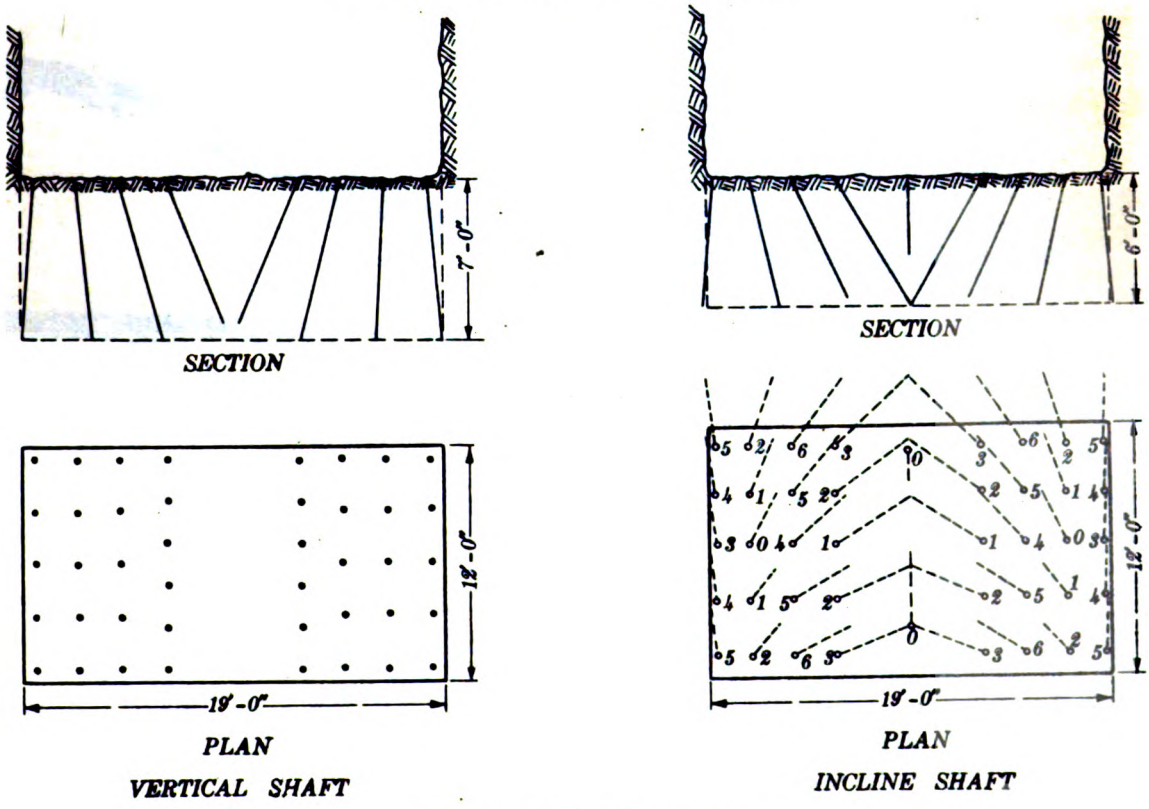

Figure 33.—Shaft sinking rounds

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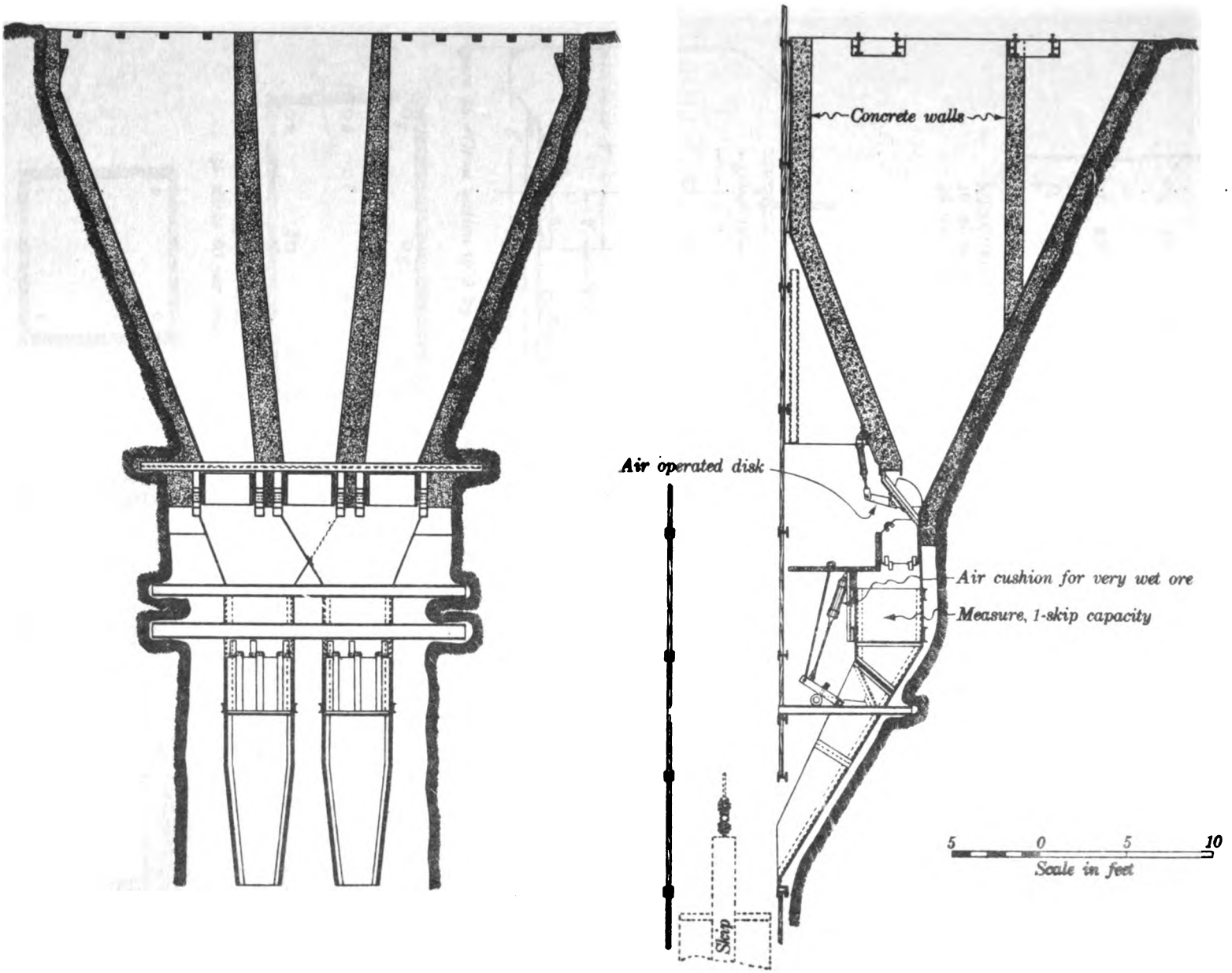

Figure 24. – Underground pocket. Total capacity 310 tons

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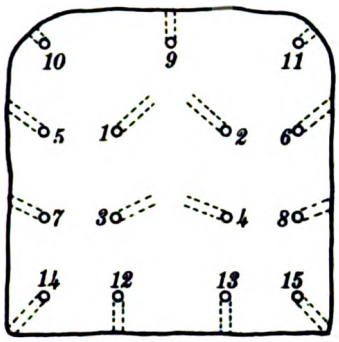
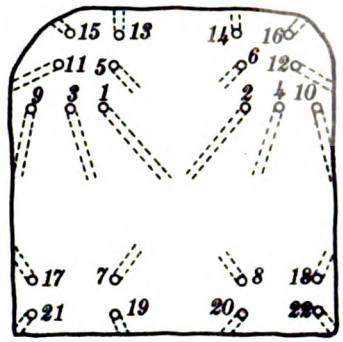


MEDIUM TIGHT ORE
40 sticks of 60 per cent
40 sticks of 35 per cent



GREENSTONE AND TIGHT FORMATION
168 sticks of 60 per cent

Figure 35.–Blasting rounds in drifts and crosscuts

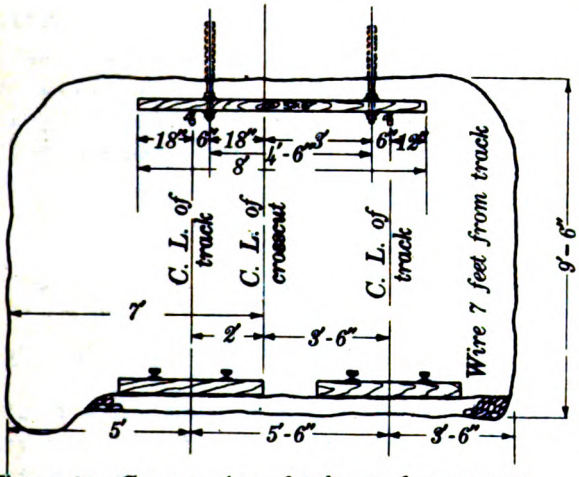


Figure 36.–Cross section of 9 by 14 foot crosscut

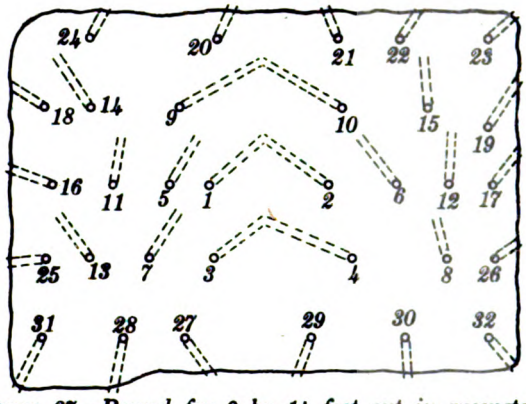
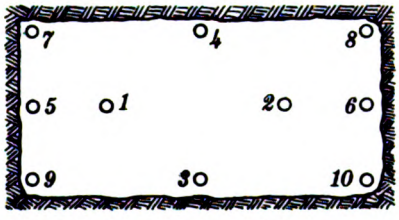
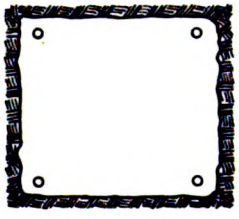


Figure 37.–Round for 9 by 14 foot cut in greenstone. 175 lbs. 60 per cent gelatine used per 6 foot cut



DOUBLE RAISE
45 sticks 60 per cent



SINGLE RAISE
12 sticks 35 per cent

Figure 38.–Raise blasting rounds

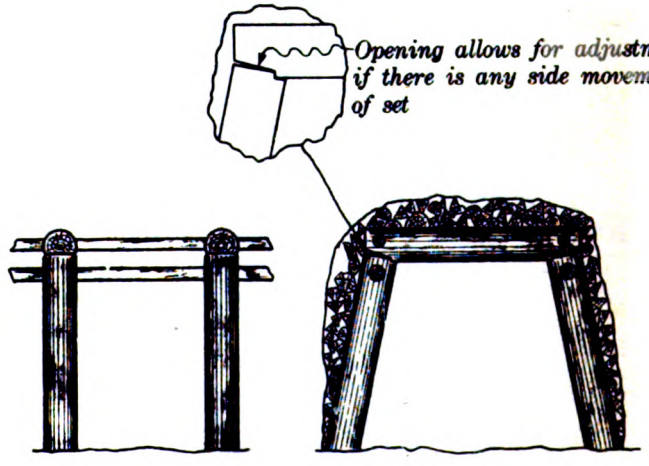


Figure 39.–Underground timber set, 8 foot cap and 8 foot post

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Average time record for average cuts in inclined and vertical shaft sinkings under pentice

Operation	Inclined shaft, quartz slates, average cut, 7.25 ft. Hours	Vertical shaft, greenstone, average cut, 6.35 ft. Hours
Rigging up	1.1	1.9
Drilling	4.3	7.7
Blasting	2.6	2.8
Ventilating	2.0	2.2
Trimming loose	.8	1.6
Mucking	22.2	17.3
Timbering	8.6 (with concrete lath)	3.3 (no lath)
Guniting	-	1.0
Delays	1.5	.8
Lunch	1.7	1.4
Putting in rails, runners, bearing pieces, solers, and misc.	1.5	1.0
Average time to complete cut	46.3 hrs.	41.0 hrs.

Shaft Stations and Pockets - See Figure 34.

In extending shafts several hundred feet shaft stations and pockets are partly excavated before the pentice is removed, so that they may be finished later without interruption to hoisting. Permanent construction is used, not only on account of relatively long life, but so that stations will not need repairs after levels are abandoned. Excavations and construction are done under supervision of engineers. Surface carpenters build forms, and underground labor completes pocket.

Crosscuts; Drifts - See Figure 35.

Single-track openings are driven from shaft to small ore bodies and through unexplored ground. The equipment consists of two drilling machines with posts, slusher unit, portable slide, locomotive, and one to four cars. The stipulated price per foot for labor and explosives is paid for finished job, including hauling dirt to shaft and preparation for track laying.

Until the ore bodies are reached it is not practicable to give development gangs more than one heading to work in. The most economical results are obtained when a definite amount of work can repeatedly be carried out on each shift; the number of men used in a heading to accomplish this depends upon the conditions. In single-track slate rock work without timber two men can drill, blast, and muck a 5 to 6 foot cut. In medium hard formation rock, two shifts (two men on shift) are required to complete a 4 to 5 foot cut. In hard formation rock various crews have been used, the most economical combination is to use eight men in four overlapping shifts. Four men are present to move equipment and drill steel to the breast, two men do the drilling, four men are again present to rig down, move out equipment, and blast. Two men trim, clean

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up fly dirt, move up slide, muck, and move out slide. They also assist in laying track. Fifty feet per week is average advance under these conditions.

Where timber is used in medium ground or ore, a shift's work consists of timbering and mucking or timbering, drilling, and blasting.

Double-track crosscuts, 9 by 14 feet (see figs. 36 and 37) in greenstone from the vertical shaft range in length from 1,600 to 2,000 feet straight from the shaft. The rock is hard drilling, breaks very coarse. Equipment consists of drill carriage for six 4-inch water-hammer drilling machines; a 2-car unit, 380 cubic feet capacity, with attached slide for loading; a slusher hoist mounted on locomotive which hauls the cars; a drill-steel truck and an extra locomotive for handling drill carriage and steel truck.

Seven men and boss make up working crew. Three 8-hour shifts are worked per day, the crews relieving each other at the breast. Average advance in greenstone was 13 feet per day, in a short run in quartz slate, 23 feet per day.

Average time record for average cut in greenstone

Operation	Average cut, 6.1 ft. Hours	Minutes
Rigging up	0	29
Drilling	4	25
Rigging down	0	26
Blasting	0	32
Ventilating	0	33
Blasting missed holes	0	10
Trimming, preparing to muck	0	34
Mucking	3	9
Track	0	31
Lunch	0	15
Delays	0	11
	11	15

Raises - See Figure 38.

Raises in narrow ore bodies are driven on the footwall without cribbing. These raises are 4 by 5 feet. Ladders are carried 18 inches from the foot, and kept close to top of raise. General practice is to carry single raises only between 25-foot sublevels. Headboards and stulls are used where necessary.

Raises in wide ore bodies are driven from loading drifts at angle of 65 . These raises are 2-compartment, cribbed with 6-inch cribbing, 4 by 4 inside. Eight-foot ladders are carried to top of cribbing; rails are used for staging. Head-boards and stulls are regular practice. Small single-drum air hoists are used to handle cribbing. Signals (air whistles with pull cord) are used in long raises. Signaling by calling and rapping on pipes are stricly forbidden.

Auger drilling machines, hand held and with feed legs, are used with auger steel and 7/8-inch quarter-octagon hollow drill steel in ore raises. Rock

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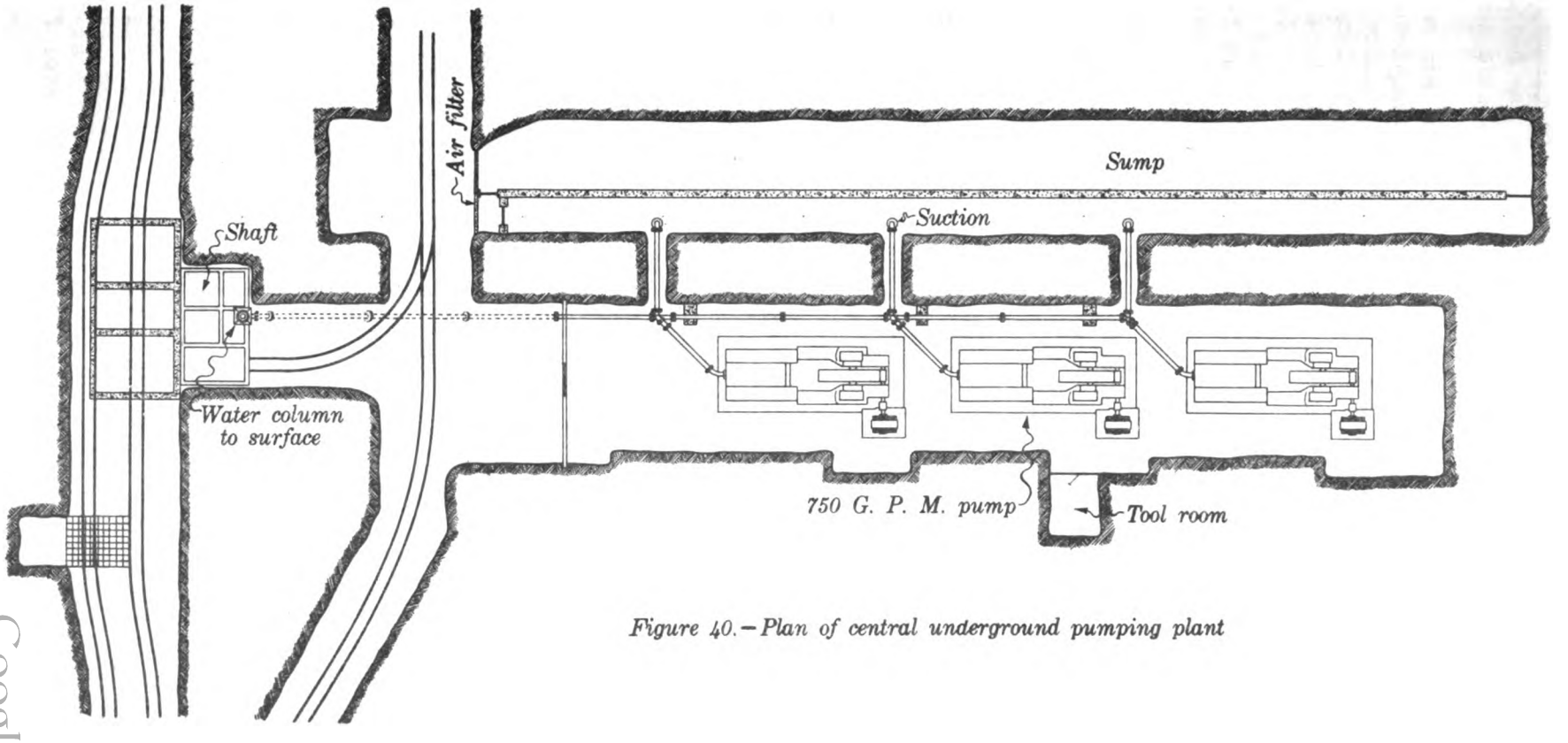

Figure 40.—Plan of central underground pumping plant

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raises are driven usually without timber, the same as single raises in ore, except that hand-rotated wet and dry stopers are used with 7/8-inch hollow and 1-inch solid hexagon steel.

General

After the ore body is reached gangs have more than one heading to work in. In the development of an ore body for the caving method and loading cars with slushers without chutes the most economical combination has been seven men in a gang composed of six miners and one swamper. The large slushing unit is set up, and contract is given the six miners. Five miners drill, blast, and timber on day shift; on night shift one miner, with the help of the swamper, mucks all the dirt, trams it to shaft, hauls timber, and places it at working places for day shift men. In soft ground, double raises, taking 6-inch by 5-foot cribbing in each compartment and drifts taking 14 to 18-inch by 8-foot timber, were driven at average cost of $3.50 for labor and explosives.

Timbering - See Figure 39.

All timber is framed on surface under contract. Timber is so framed and stood up underground as to withstand both vertical and side pressures. Sets are stood at 5-foot centers and closely lagged with 6-foot split cedar. Raises are cribbed with 6-inch round, with 6-inch joggle.

Regular mining timber consists of the run of local woods - hemlock, tamarack, and hardwood, excluding birch. In sublevel caving main level development of small ore bodies, and exploratory work, regular 8-foot mining timber is used. In main-level work in large ore bodies select hemlock saw logs, 14 to 24-inches in diameter, are used. In sublevel work in open stopes 7-foot regular mining timber is used.

All ore-development openings are timbered, and no work is done under exposed back; headboards are used in drifts and raises.

Pumping - See Figure 40.

The total drainage from the property averages approximately 900 g.p.m. In the low water periods of summer and winter about 700 g.p.m. is pumped to surface. This amount increases to 1000 g.p.m. in seasonal periods of heavy rain fall. To a considerable extent dikes control the underground water circulation. Approximately three-quarters of the water is permanently collected from upper dikes and workings, and one-quarter will follow the working of the present dikes down. The porosity of the ore averages 30 per cent. The hanging-formation ore appears to be saturated, whereas there is a small amount of residual water in the foot-formation ore.

The mine is laid out so that the water flows to the central vertical shaft. The pumps throwing the water to surface are located on the 27th level, 2,000 feet vertically from surface. Seventy-five per cent of the mine workings are above this level at the present time. Small electric relay pumps are used in the lower workings and bottoms of the shafts.

The pumping plant consists of three 750-gallon, 6¾ by 24 inch horizontal duplex pumps, driven by 400-hp., 2,300-volt synchronous motors. Pumps and water column are protected by air chambers and alleviators. Power feed line is in duplicate. Discharge column is made up of three weights of pipe, hydraulic, extra heavy, and standard, welded into 100-foot lengths, supported by special cast-steel base elbow and reenforced concrete pier. Alternate lengths are hung on the shaft sets for support, the other lengths are clamped to sets for alignment.

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One pump handles water for greater part of the time. In high water periods, one pump is run continuously and one part time. The third pump is a reserve unit.

The pump room is in greenstone, 28 by 150 by 12 feet high, unsupported. Three coats of gunite were applied to walls and roof. Sump is 18 by 160 by 12 feet high, divided lengthways by concrete wall for settling and cleaning. Forty-eight-hour water storage is provided by water drifts with dams.

MINING (STOPING); SUBLEVEL CAVING METHOD

After the ore body is developed, as shown in Figure 4, the double raises are connected 17 feet below their tops, with 8-foot timber drifts.

The ore body is then ready for mining, which consists of driving north or south to the hanging or foot, and "stoping" the side and back pillars in retreat.

Figures 41 and 42 show the method of taking the ore in retreat. It will be noted that the "stopes" on one side of the sublevel crosscut are large and those on the other, small. The large "stopes" take down the hogsback above as follows:- The side lagging is removed between two sets, and a light cut blasted, care being used to protect the pillar around the caps of the sets. The stope is then carried up, enlarging the roof as much as possible without causing it to cave before the proper height is reached. The stope has an inclination of 45 to 50° at a right angle to the sub crosscut. At a height of 12 feet above the bottom of the stope a "dog hole" is holed into the stope from the direction of retreat. This "dog hole" is used as travel road in the final drilling, which is to fan out the opening under the hogsback above. After the ore is drawn and the stope filled with cave, blasting is continued in the cave between the chunks to shake out the ore mixed in, in the caving.

The determining conditions to which this method of mining is adapted are: (a) A dipping and pitching irregular ore body which does not lend itself to topslicing. (b) A medium-soft ore which breaks fine, yet stands well and is not free caving. (c) A hard capping which caves in medium sized blocks without much fines, and which is easily controlled.

The drilling and blasting are mostly by breast stoping on an incline, with some slice holes. Auger machines held in the hand or mounted on feed leg are used with auger steel and hollow quarter-octagon steel. The ore runs by gravity to the sublevel crosscut and is scraped to the raise. Fifteen hp., D. C. slusher hoists with 42-inch hoe, and round-back box-type of scrapers are replacing smaller equipment in handling ore from mining places to raise. Every raise is a 2-compartment cribbed raise, 4 feet square inside. One compartment is lined with hardwood plank and used as an ore pass. The other has ladderway and timber slide, used also for ventilation. Miners do not leave working places for timber but assist in hoisting it to their place with their slusher hoist. A sublevel 30 feet above the main hoisting level is connected with each raise and to the level above by a 22° inclined trackway in the footwall. Timber is distributed on trucks from shaft collar to working place.

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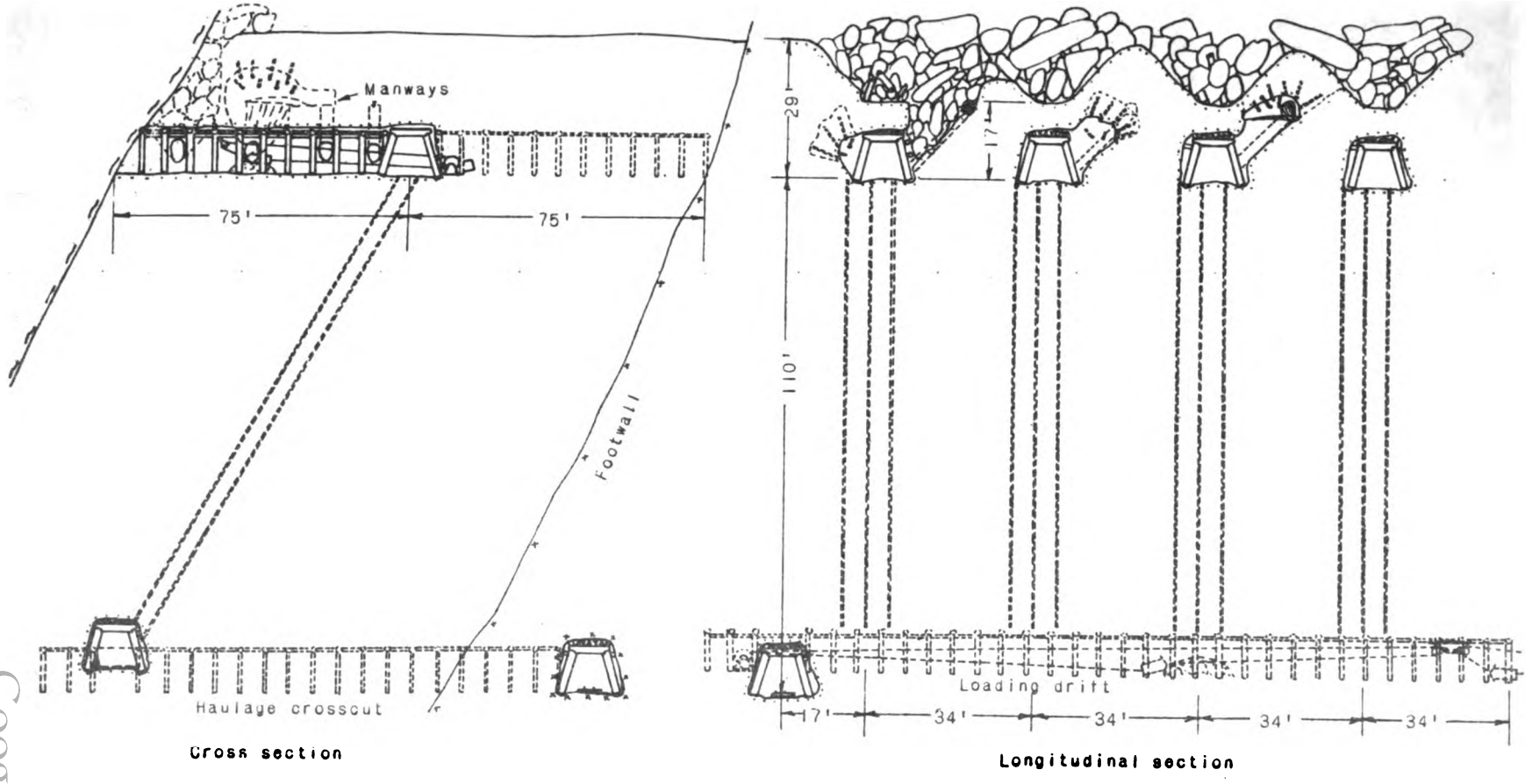

Figure 41.- Single-entry sublevel slushing with 17 pillars, No. 4 shaft

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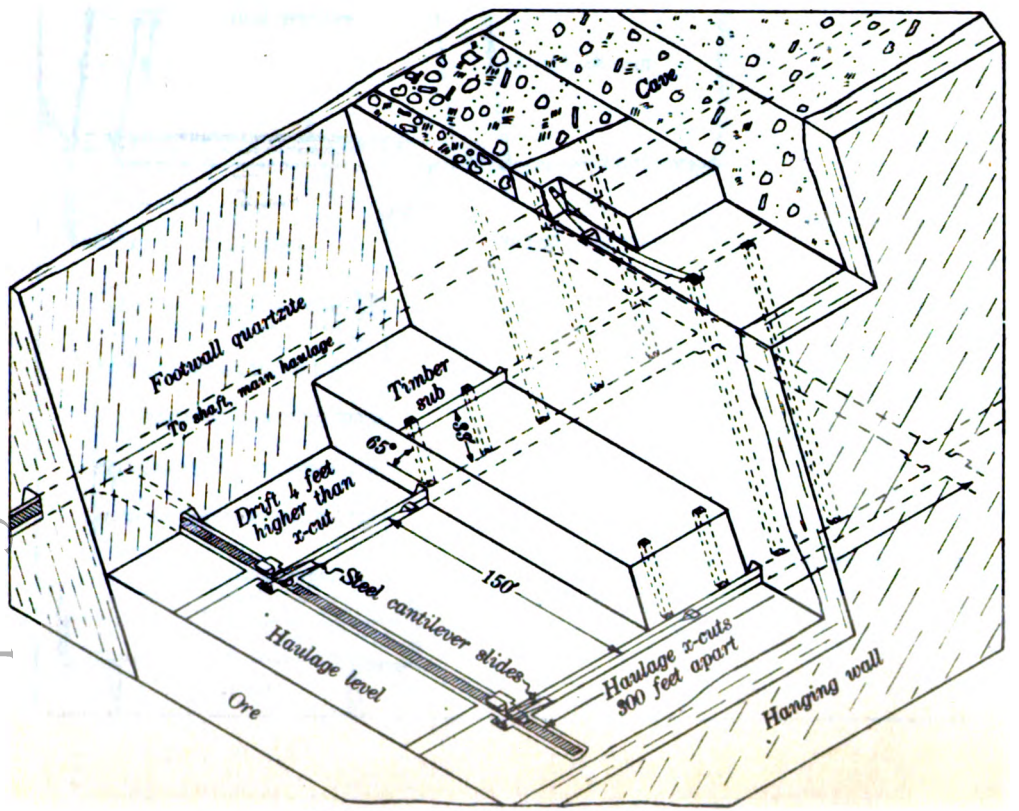

Figure 42.—Sublevel caving method of mining

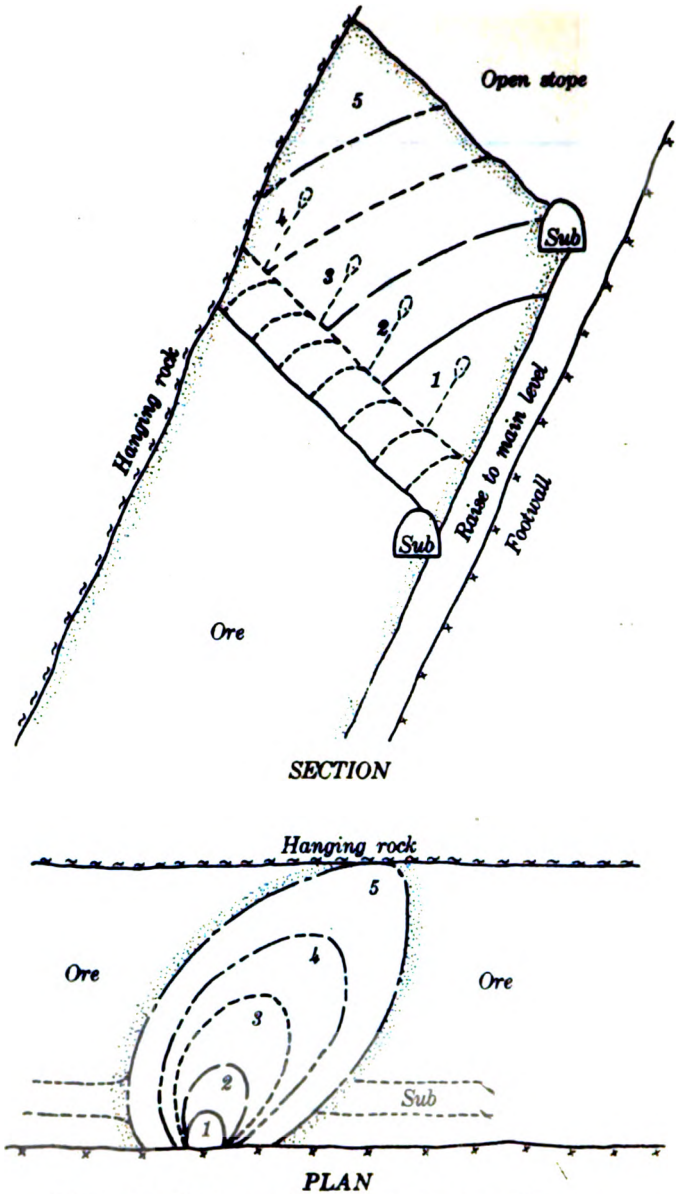

*Figure 43.—**Stoping** method used in hard ore. Numbers indicate successive steps in stoping operations*

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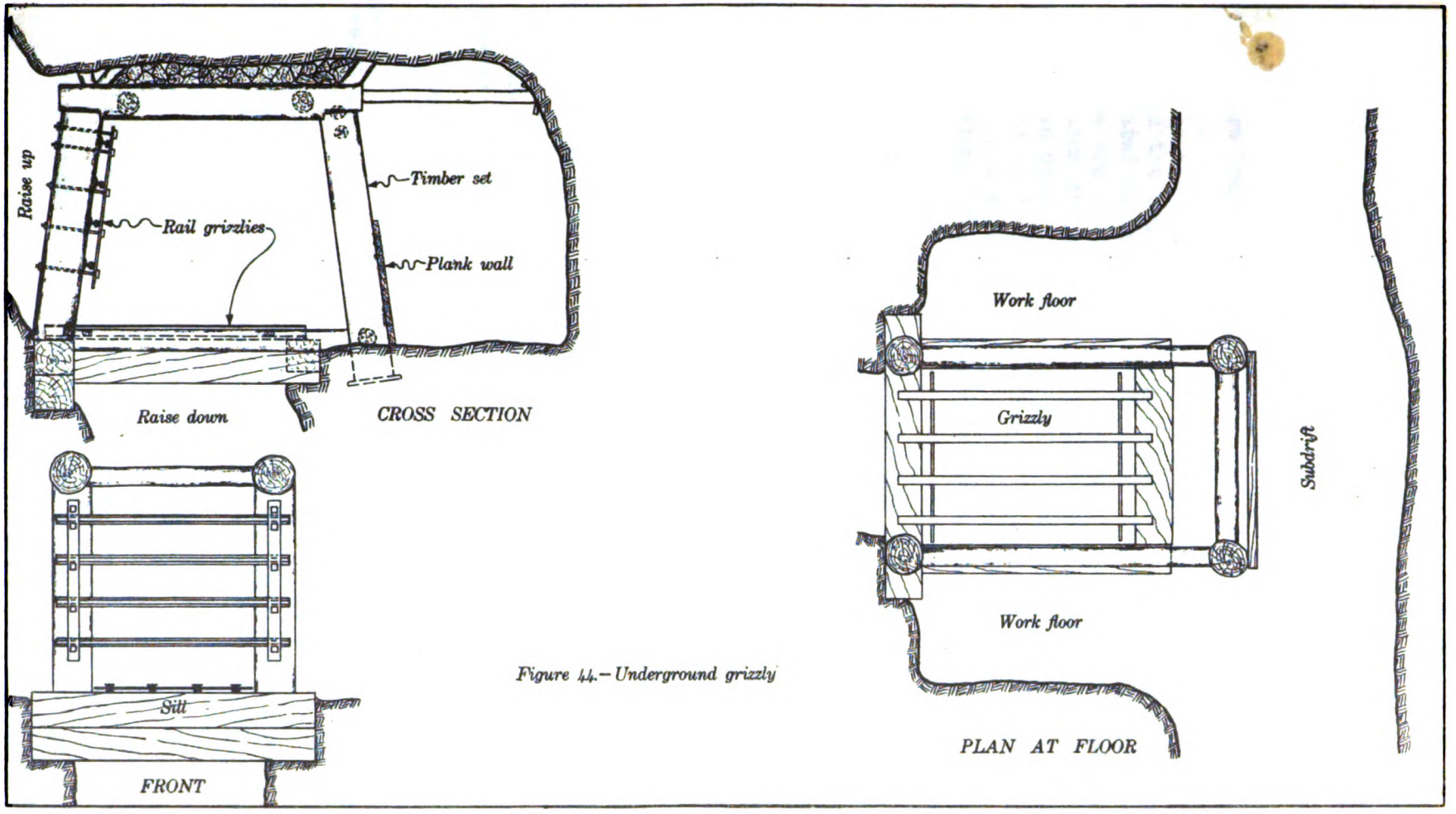

Figure 44.– Underground grizzly

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The ore compartment of each raise is covered with an 8-inch grizzly made of old rails. Oversize chunks of ore are sledged here. Rock is picked at the grizzly, accumulated, and sent out separately.

MINING (STOPING); OVERHAND SUBLEVEL OPEN STOPING

After the ore body is developed, as shown in Figure 13, stoping proceeds as follows:

Beginning on the top sublevel (see fig. 43) the ore is sliced out around a centrally located raise on an inclination of 50° with the horizontal. At this inclination the ore runs by gravity down the raise. As the opening is enlarged, 10-foot overhand stope holes are drilled, chambered, and heavily loaded with 60 per cent gelatin powder. The stope holes take at least two thirds of the height of the pillar, and as the operation is repeated toward the hanging the pillar breaks down on the foot, holing through to the open stope above. Slicing with overhand stope holes is carried on until the hanging rock is reached.

The operation is repeated around the same raise on the subs below until the ore body is divided in two parts, which may be mined each way in retreat. The practice from this point is to retreat with a face slightly sloping backward wfrom the stope and diagonal with the strike, the foot side being ahead in retreat. The diagonal face takes advantage of the stratification of the ore in breaking and caving.

At times when the ore body is irregular in width and lacks vertical height it becomes necessary to stope into raises at 33 foot centers to maintain a steady production. At such times all stoping is carried on in the manner described for opening up an ore body. The determining condition to which this method of mining is adapted, is a narrow, irregular ore body, which is firm enough to stand well but dangerous to work under, when undercut. It is necessary to relieve the weight by keeping the back of openings arched at all times. A rule, that no one shall enter these stopes without safety belts properly attached, is strictly enforced.

The ore broken by this method contains up to 40 per cent chunks, especially the manganiferous grades. To facilitate handling the ore on the main level, a grizzly is maintained on the first sub 30 feet above the level. A chute is built above the grizzly to control the flow of ore on to the grizzly (see fig. 44).

On account of small amount of timber used no special arrangements are made for handling it; the practice is to hoist timber in raise nearest working place.

UNDERGROUND TRANSPORTATION

Locomotives (Trolley-Wire Equipment)

Four 2-ton locomotives are used in short-haul development work. Eleven 4-ton locomotives are used for gathering cars, and short hauls to the

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shaft. Fourteen 6-ton locomotives are used for long hauls from gathering yards to shaft, and for long hauls from ore body direct to the shaft.

Cars - See Figure 45.

Special cars are used in extensive rock jobs. Two hundred-40-cu.ft. round-bottom, rocker-type, side-dump cars carrying 2-1/4 tons are used throughout the mine. Cars are fitted with springs, 14-inch chilled cast-iron wheels, cast-iron housings, roller bearings, and automatic couplers. This size car was chosen as the largest car of this type to be economically used under crushing conditions. It prevents spillage along track, is easily dumped and cleaned, and allows dumping on a grizzly at the shaft, which is necessary when the ore is not reduced in the ore body.

Ten and fiteen car trains (depending upon haul) are used where loading conditions are good. Five-car trains are used where loading conditions are poor and it is necessary to increase the working force at the chutes. When cars are gathered for long haul to shaft, 20 to 25 car trains are made up, locomotives pulling cars both ways.

Tracks

Grades are laid at one half per cent in favor of loads. Forty-pound rails with welded bonds at 24-inch gage laid on 5-inch ties, 18-inch centers, is general practice. Cast-steel frogs, machined switch points, and switch throwers with inclosed springs, are used. When gathering is done locomotives pull empties into the ore body and push out loads. In this case automatic switch throwers, operated from locomotives, are used.

Signals

Both hand and trolley operated signal systems are used underground for protection in transportation. Blue lights are used to designate safety zones on haulageways.

A return signal system, using both lights and horns, is used in hoisting.

Loading Cars

Two types of chutes are used. In the open-stope mining method, where the chunks are troublesome, the type shown in Figure 46 is used. Figure 47 is used elsewhere.

In the large ore body on the west end of the property, where the sub-level caving method of mining is used and subsidence is over a large area, surface water seeps into the ore body from overhead in both the spring and fall. The ore does not get properly dried out at any time and is damp enough to make it sticky and difficult to handle in chutes. Under this condition the ore is loaded into cars with 25-hp. slushers and hoe-type scrapers, at a saving over chutes in recent loading of 7 cents per ton (see figs. 42 and 48).

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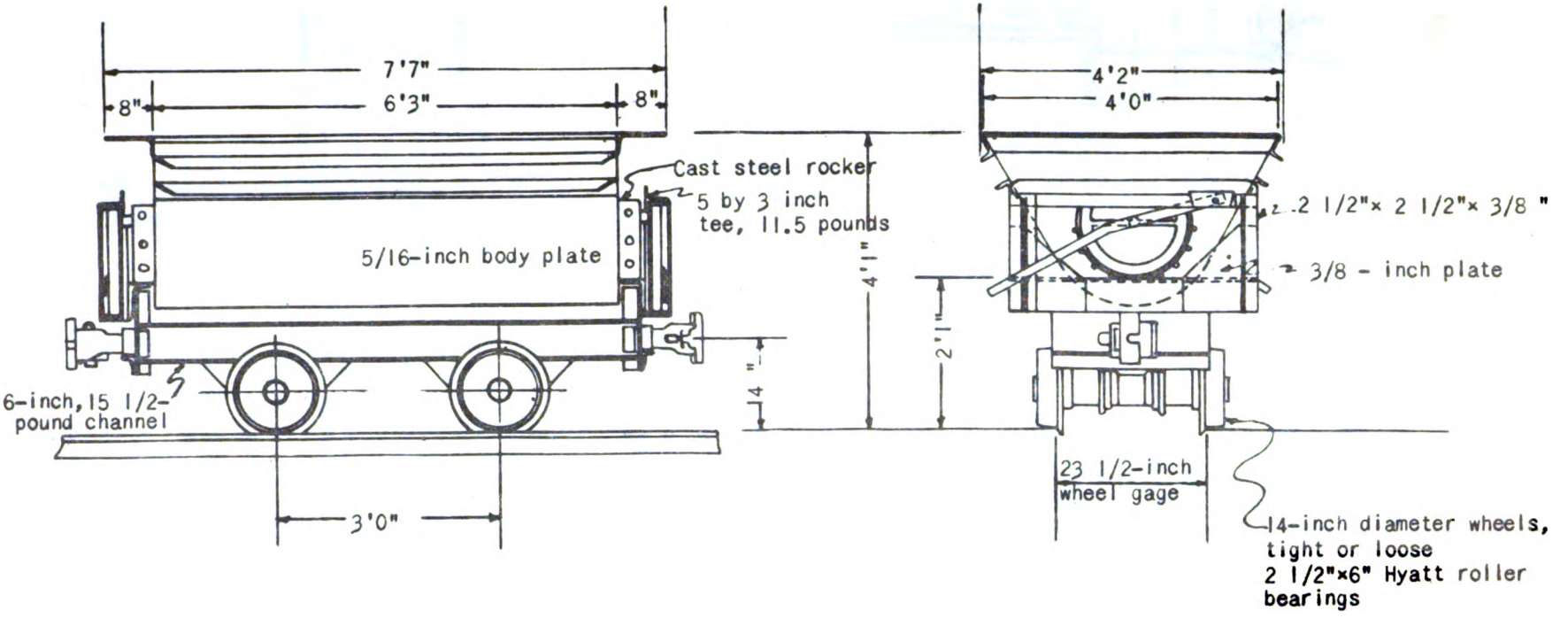

Figure 45.- Rocker dump car; capacity, 40 cubic feet

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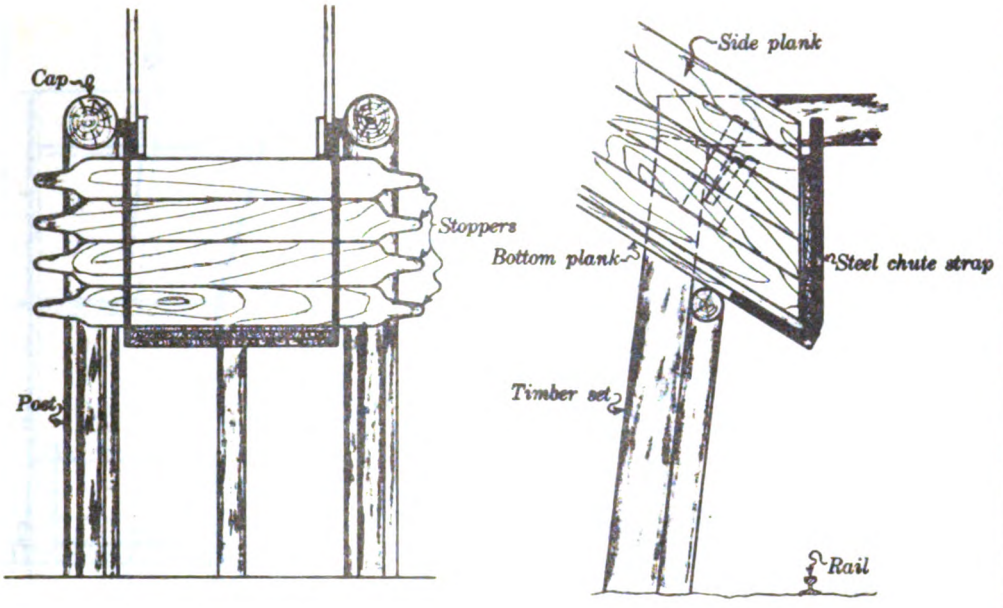

Figure 46.— Underground loading chute

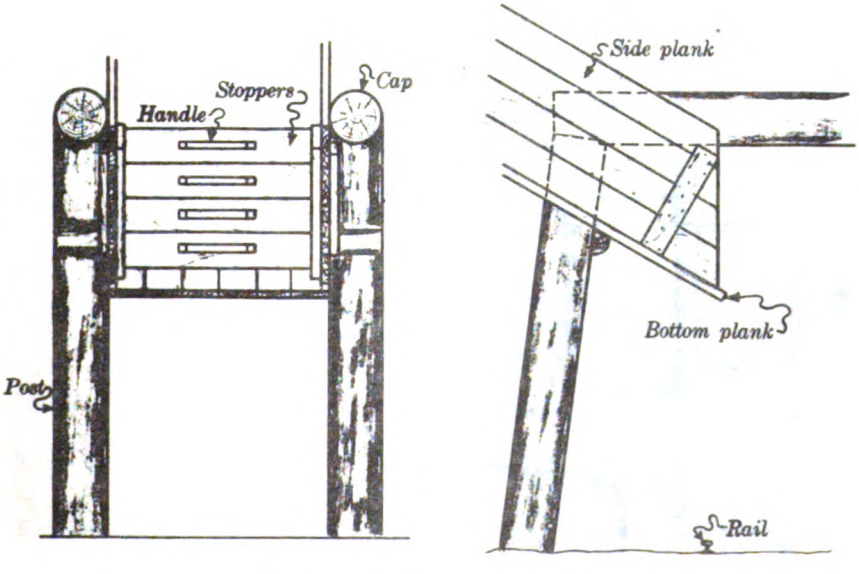

Figure 47.— Underground loading chute

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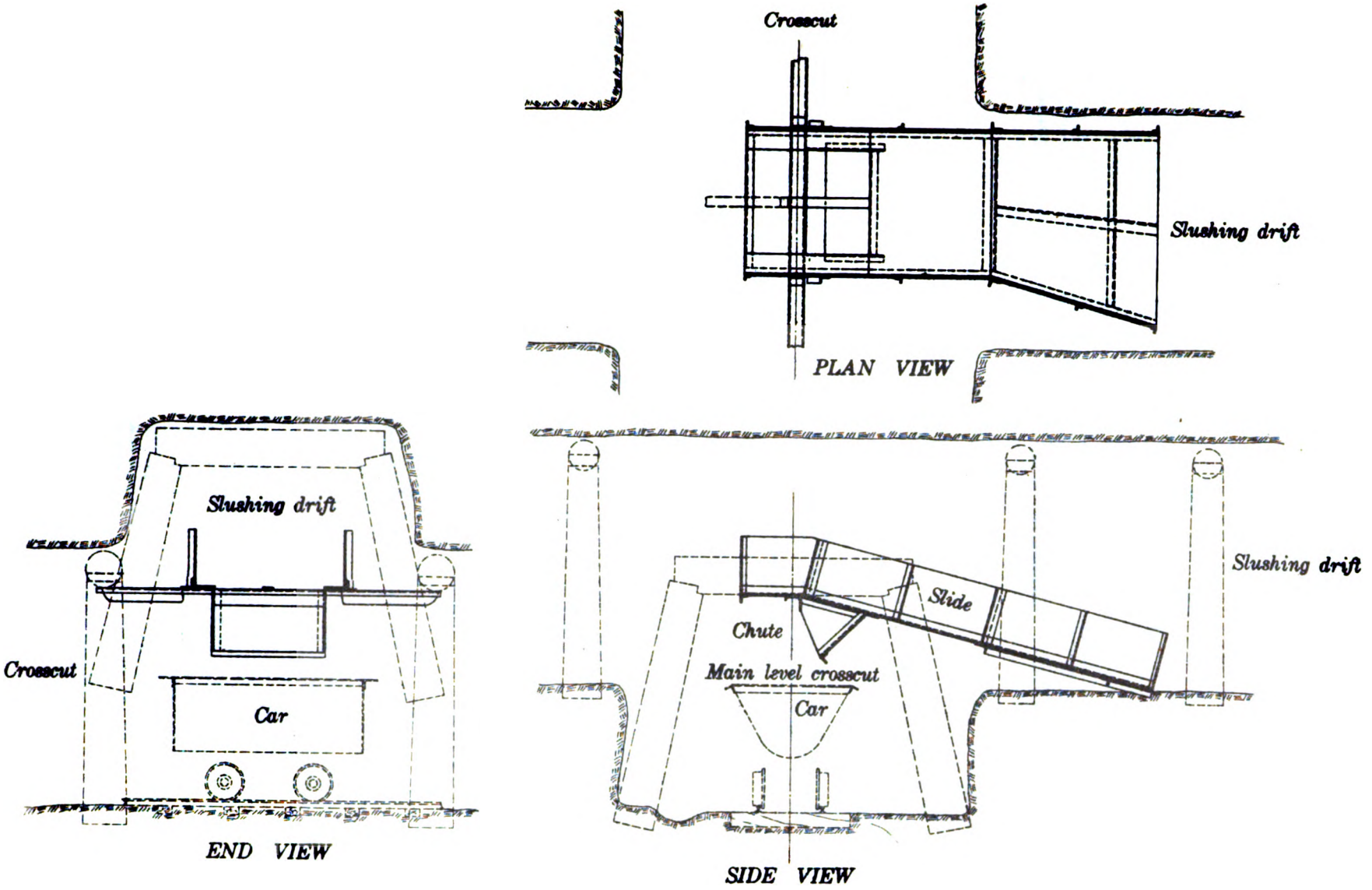

Figure 48. — Steel cantilever-type loading slide, for underground loading

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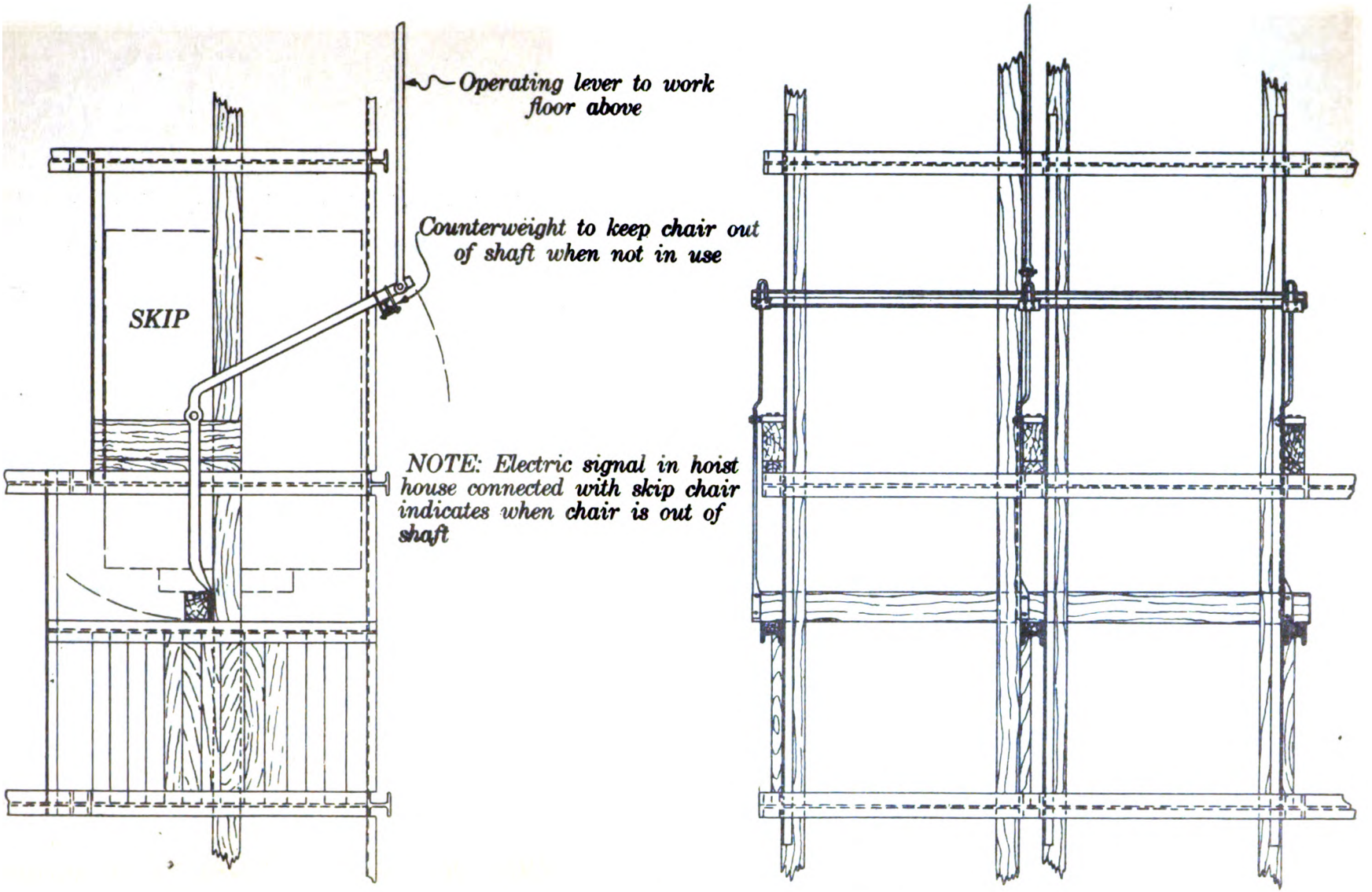
Operating lever to work floor above
Counterweight to keep chair out of shaft when not in use
SKIP
NOTE: Electric signal in hoist house connected with skip chair indicates when chair is out of shaft

Figure 49.— Underground skip chair

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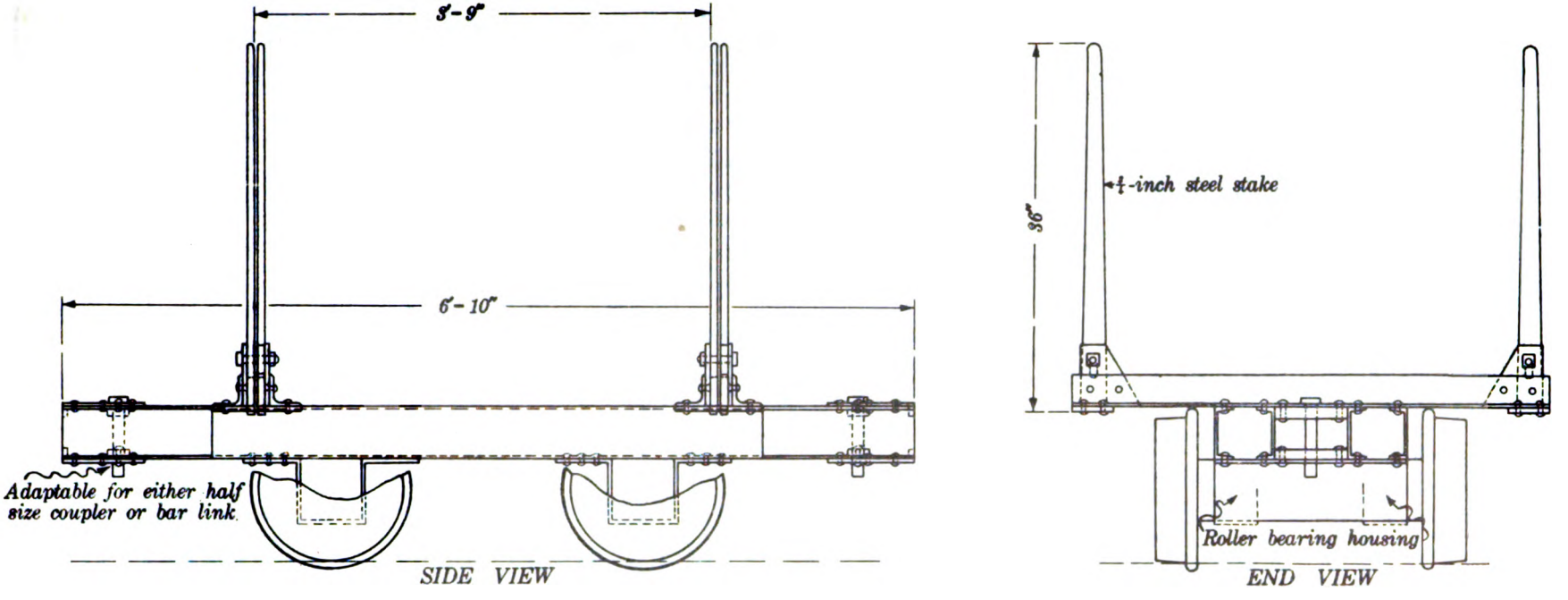

Figure 50. – Underground timber truck, all steel

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Shaft Pockets, Skip Loading Measures, Storage Pockets

To handle production peaks of several grades and a large amount of rock (10 to 15 per cent of ore production) storage facilities have been found necessary. Figures 10 to 22 are drawings of latest types of shaft pockets, storage raises, etc.

Storage raises are inclined at 70° from the center compartments of shaft pockets. They are arranged with gates, which may be used to control the ore, or be left open and allow the ore to be drawn through the pocket to the skip measure. In handling wet ore, an air cylinder control is used on skip measure door. Figure 49 shows skip chair in use in vertical shaft, where hoisting is done from several levels.

TRANSPORTATION OF SUPPLIES AND MATERIALS

Timber

Timber is hauled on trucks to shaft collar, piled on skidways, loaded on underground timber trucks (see fig. 50). Timber trucks are lowered and hoisted in shafts on double-deck cages. The trucks being made up with tram-car running gear are readily portable. From the shafts there are three methods of distribution underground.

In the largest ore body, where considerable timber is used and the level interval is 125 feet, an inclined trackway (22°) is used to lower the timber to a sublevel above the main level. The timber is unloaded from trucks at the raises and hoisted to working elevations. In medium-size ore bodies, where main level interval is over 200 feet, a small cage is operated to lower timber from trucks to intermediate sublevels. In small ore bodies timber is hoisted directly from trucks on main level to working places.

Drill Steel

Drill steel is handled in 2-ton racks from the shop to shaft stations. Underground, special trucks are used to serve places using large amounts of steel. Augers and hollow steel, for work in ore, are piled at convenient points, and miners carry them to working places as they pass. In special places, steel is delivered.

Explosives

Powder is delivered in 2-ton lots to steel magazines near the collar of each shaft. Under strict regulation it is sent to an underground magazine (see fig. 51). Part of the powder is delivered to the miners from the magazine, part of it is called for by them. All powder is issued on order slips from foremen and charged to the working place. Caps and fuse are handled in the same way.

Miscellaneous Supplies

Practically everything is handled on the shaft cages, except heavy

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pump equipment, which is hung under the cage. The cage in the vertical shaft is 22 feet long. Pipes, plank, etc., may be handled without lifting the bonnet. Figure 7 shows chairs on bottom of the cage operated from within the cage.

WAGE, CONTRACT, AND BONUS SYSTEMS

The mine operates two shifts per day, beginning at 7:00 a.m., ending at 1:00 a.m., with one-half hour lunch periods, and one hour between shifts.

The schedule of wages in effect stipulates the minimum rate each class of labor is to receive, whether or not in contract. Development work of all kinds is done on contract. In large rock jobs, such as shaft sinking and double-track crosscuts, a flat rate per foot for labor only is set at the beginning of the job and remains unchanged. Explosives and other materials are furnished by the company. It has been difficult to give a large number of men in one contract an explosive contract. For development in ore and small rock jobs prices are set per foot for labor and explosives, the company furnishing other supplies. The ground is classified and prices set according to the type of ground. Slight variations in ground are not recognized.

In breaking ore, a flat rate 10 per cent above minimum or company account rate is paid. Special arrangements are made to give this work close supervision which, together with the 10 per cent bonus, is depended upon to get satisfactory results in extraction and efficiency.

VENTILATION

Natural ventilation provides sufficient circulation throughout the mine. In the winter an excess amount of air tends to flow through the mine; in the hot months of the summer there is a slight shortage at the west end of the workings. The central shaft is downcast, the two other shafts are upcast. Circulation is controlled by mechanically and hand operated ventilating doors. Two 5 and 15 hp. D.C. and A.C. fans are used with 12 and 16 inch flexible and metal tubing to convey air to working places.

FIRE HAZARDS

The principal fire hazards appear to be defective electrical construction and open lights. Special effort is made to conform to approved practice in electric wiring, and all current is shut off from underground workings between shifts. The three shafts are wet, and two of them are practically fireproof. All shaft stations are fireproof. There is no timber between the shafts and the footwall. The humidity is high underground, and damp conditions prevail. There are no thoroughly dry places on the property. Fireproof construction is used in all pump rooms, workshops, powder houses, etc. Smoking is prohibited at timber-distributing points. Old levels are sealed off from each shaft, and working levels have fire doors by which the air currents may be controlled. An ethyl mercaptan feeder is placed on the air line to give special warnings to all underground men in case of fire or other emergency. Soda ash extinguishers are maintained at shaft stations. Carbon tetrachloride extinguishers are kept in pump houses, converter rooms, powder houses, and two in each ore

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body. Provision is made to turn air lines into water lines at each shaft. One hundred-foot reels of fire hose are located on working levels.

Five sets of McCaa 2-hour oxygen apparatus, and brattice material, are located on surface at the central shaft. Ten All-Service gas masks are distributed over the property. Six fully trained teams are maintained for fire fighting. Names of trained men and simple directions to follow in case of fire are posted. Training as outlined by Bureau of Mines is given. This work is intensified by the bureau itself every year or two. At the last visit of the bureau training car an underground fire problem was worked out. Over 40 men, including part of the supervising force, participated.

SAFETY METHODS AND FIRST-AID ORGANIZATION AND TRAINING

The management of the Montreal Mining Co. has been making special efforts to promote accident prevention on the property for several years. To this end a general safety conference is held each month, attended by representatives of the mines under Oglebay Norton & Co. management. The mine representatives consist of safety engineers, department foremen, mining captains, and superintendents. At these meetings the individual gets the attitude of the management, there is an interchange of ideas, unusual accidents are discussed, and practices are established as standard. Comparative records of the different properties are kept and a trophy rewarded for the best record. A friendly rivalry has developed. On the property, a safety engineer, assistant engineer, and three inspectors, spend their full time in the various phases of accident prevention work. To assist the safety department in their work, various organization plans have been used. At present the following methods are in effect:

A general safety committee, composed of safety men, department heads, mining captains, and superintendents, meets each week. The regular order of business includes review of accidents and "near" accidents; reports of inspections made of the mine, equipment, safety devices, and cleanliness; progress reports on jobs pertaining to accident prevention; suggestions; and review and discussion of standard operating practices. A superintendent presides, and the safety department records the proceedings. Matters at these meetings are not assigned to department heads or committees. Suggestions are discussed; they are later taken up by the safety department for investigation and recommendation, and are handled like any other business on the property.

A foremen's meeting is held once each week for underground foremen, and bimonthly for surface foremen. The underground foremen are divided into three groups, representing three territories underground. Details of safety work are discussed, but the main object of these meetings is to educate the foremen in safety work. Employees' meetings are held periodically underground and in the change house. Short talks are given by members of the supervising force and employees.

An elaborate system of bulletins is maintained on surface and underground. Bulletins are furnished by the safety department, the National Safety Council, and a commercial service.

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Public safety meetings or "get-togethers" are held each month during the winter. The program consists of entertainment, safety picture, and safety talk. In addition to disseminating information and maintaining interest in a general way, the safety department makes special effort to keep in personal contact with the men. A rigid system of inspection is maintained. Analytical records are kept. Infractions of safety rules are met with disciplinary measures from a special committee. Rewards are given for good records.

The inspectors have been of especial help in education, by reading and discussing the rules governing the work of all classes of labor in small groups on the job.

The following protective clothing is compulsory - goggles, gloves, hard-toe shoes or rubbers, hard-crowned hats. The company furnishes goggles, and part of the cost of hats.

Since the adoption of the foregoing intensive methods of safety promotion, there has been a marked decrease in both the frequency and severity of accidents, and the attitude of the man has entirely changed toward accident prevention work.

First Aid

First-aid training, as outlined by the Bureau of Mines, is carried on regularly in winter months. The supervising force and 15 per cent of the workmen have been kept trained in small groups. The Bureau of Mines recently trained the men very successfully in large groups. Under this plan, training for all employees is contemplated. Special training in artificial respiration is given rescue men and electrical workers. All underground foremen carry pocket first-aid kits for abrasions. Complete emergency kits, consisting of antiseptics, restoratives, bandages, splints, blankets, and stretcher, are readily available at each shaft. Ambulance service to a near-by hospital is maintained day and night. Two doctors reside at the property.

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TABLE 1. - SUMMARY OF COSTS

Number of Mine - No. 4 Shaft Period Covered: Year 1928
Long tons ore hoisted during period: 450,000
Mining method - Sublevel caving

	Labor	Super-vision	Comp. air, air drills, drill steel	Power Cost	Explo-sives	Timber	Misc. Supp.	Total
	$	$	$		$		$	$
Development								
In ore	0.051	0.004	0.009	-	0.011	-	0.002	0.077
In rock	.054	.003	.043	-	.014	-	.003	.117
Mining	.224	.035	.020	-	.061	-	.020	.360
				$				
Transportation	.121	(1)	-	(2)0.009	-	-	.025	.155
Timbering						$		
General	.149	(1)	-	-	.007	(3)0.060	.008	.224
Pumping, ventilation, misc. accts.)	.033	-	.019	0.27	-	-	.008	.087
Hoisting	.073	-	-	(4) .114	-	-	.002	.189
Surface expense Chargeable	.061	-	-	-	-	-	.009	.070
Totals	.766	.042	.091	.150	.093	.060	.077	1.279
Deferred rock development	-							.06

(1) Supervision included in account of operation.
(2) Includes power cost of slushing.
(3) Timbering account includes cost of timber used in development and mining.
(4) Includes steam power for ore hoisting.

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TABLE 1-A -SUMMARY OF COSTS

Number of Mine - Nos. 5 & 6 Shafts Period Covered: Year 1928
Long tons ore hoisted during period: 630,000
Mining method - Sublevel overhand open stoping

	Labor	Super vision	Comp. air, air drills, drill steel	Power cost	Explo-sives	Timber	Misc. Supp.	Total
Development	$	$	$		$		$	$
In ore	0.135	0.009	0.022	-	0.037	-	0.002	0.205
In rock	.078	.009	.055	-	.018	-	.002	.162
Mining (Includes grizzlying	.138	.017	.010	-	.079	-	.011	.255
Transportation	.095	(1)	-	$ 0.010	-	-	.015	.120
Timbering	.045	(1)	-	-	.002	$ 0.043	.004	.094
Pumping, ventila-) tion, misc. accts.)	.040	-	-	.020	.037	- -	.009	.106
Hoisting	.080	-	-	.059	-	-	.019	.158
Surface expense Chargeable	.052	-	-	-	-	-	.008	.060
Totals	.563	.035	.107	.106	.136	.043	.070	1.160
Deferred rock development -								.06

(1) Supervision included in account of operation.

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TABLE 2 - SUMMARY OF COSTS

IN UNITS OF LABOR, POWER, SUPPLIES

Number of Mine - No. 4 Shaft Period Covered: Year 1928
Long tons ore hoisted during period: 450,000
Mining method - Sublevel caving

	Development	Mining	Timbering	Total
a. Labor (man-hours per long ton)				
Breaking (drilling and blasting)	0.081	0.176	-	0.257
Timbering (in working place)	.045	.074	-	.119
Mucking	.022	.102	-	.124
Haulage	1 .011	.210	-	.221
Timbering (general)	-	-	0.258	.258
Pumping, ventilation, misc. accts.	.031	.031	-	.062
Supervision	.009	.045	-	.054
Hoisting	.017	.116	-	.133
Surface labor - chargeable	.006	.080	.022	.108
Total underground & surface labor chargeable to underground accts.	.222	.834	.280	1.336
1 Developers tram own ore to large extent.				
Average tons per man per shift				5.98
Labor percentage of total cost				65
b. Power and supplies				
Explosives (lbs. per long ton)	.196	.394	-	.59
Kind and grade		35% and 60% L.F. Am.Gel.		
Timber (b.m.)				2.76
Power (kw.h. per long ton)				
Air compression				3.31
Pumping				1.80
Hoisting (cage)				.62
Haulage, slushing, lighting				.51
Total -				6.24
Steam, coal (lbs. per long ton)				
Ore hoisting				.32
Other supplies in per cent of total supplies and power				17.1
c. Percentage - total cost	15.7	66.8	17.5	100.0

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TABLE 2-A SUMMARY OF COSTS

IN UNITS OF LABOR, POWER, SUPPLIES

Number of Mine - Nos. 5 & 6 Shafts Period Covered: Year 1928
Long tons of ore mined and hoisted: 630,000
Mining method - Sublevel overhand open stoping

	Development	Mining	Timbering	Total
a. Labor (man-hours per long ton)				
Breaking (drilling and blasting)	0.155	0.192	-	0.347
Timbering (in working place)	.055	-	-	.055
Mucking	.090	.024	-	.114
Haulage	.043	.131	-	.174
Timbering (general)	-	-	0.078	.078
Pumping, ventilation, misc. accts.	.040	.035	-	.075
Supervision	.024	.023	-	.047
Hoisting	.037	.110	-	.147
Surface labor, chargeable	.080	.007	.005	.092
Total underground and surface labor chargeable to underground accts.	.524	.522	.083	1.129
Average tons per man per shift				7.08
Labor percentage of total cost				63
b. Power and supplies				
Explosives (lbs. per long ton)	.36	.49	-	.85
Kind and grade		35% and 60% L.F. Am.Gel.		
Timber (b.m.)				1.65
Power (kw.h. per long ton)				
Air compression				4.60
Pumping				2.82
Hoisting				4.49
Haulage, slushing, lighting				.70
T o t a l -				12.61
Other supplies in per cent of total supplies and power				16.1
c. Percentage - total cost	31.6	60.3	8.1	100.0

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Table 3 - Detail of Costs in Units of Labor, Power, and Supplies

NO. 4 SHAFT	Development						
Sublevel caving	Main level drifting & X-cutting rock	Main level drifting & X-cutting rock	Sublevel drifting & X-cutting rock	Raising two compart.	Main level drifting & X-cutting ore	Raising two compart.	TOTAL all development
Size of opening	9 x 9	8 x 8	7 x 7	5 x 10	9 x 12	5 x 10	
Timbered or not	8'tbr.	None	None	6"crib.	Logs	6"crib.	
Physical properties of rock	Medium hard	Medium hard	Hard	Medium hard	Medium soft	Medium soft	
A. LABOR (man-hours per ft.)							
(a) Breaking (drill. & blast.)	4.41	4.98	6.79	4.65	3.94	2.78	3.87
Timbering	2.77	-	-	3.73	2.21	2.33	2.16
Mucking	2.02	2.86	2.50	-	1.09	-	1.07
Haulage & hoisting	-	-	-	-	-	-	1.78
Supervision	-	-	-	-	-	-	.56
Total labor	9.20	7.84	9.29	8.38	7.24	5.11	9.44
Feet per 8-hr. shift	.864	1.148	.861	1.048	1.104	1.566	1.127
(b) Trimming, headboards, preparation, etc. included.							
B. POWER & SUPPLIES (per foot)							
Explosives (lbs. per ft.)	11.6	12.9	8.1	6.6	7.4	4.9	8.3
Timber (b. m.)	64	-	-	72	89	72	60
Total Power (kw.h.)							
1. Air compression	-	-	-	-	-	-	56
2. Hoisting	-	-	-	-	-	-	(5 kw.h.) (258# coal)
3. Haulage	-	-	-	-	-	-	1.6
Other supplies in per cent of total power and supplies	-	-	-	-	-	-	31
C. LABOR (per cent) total cost							
Labor, including supervision	-	-	-	-	-	-	55
Power & supplies, including comp. air, drill steel, etc.	-	-	-	-	-	-	45

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Table 3-A - Detail of Costs in Units of Labor, Power, and Supplies
Rock Development

NOS. 5 & 6 SHAFTS sublevel overhand open-stoping	Main level drifting & X-cutting rock	Main level drifting & X-cutting rock	Sublevel drifting & X-cutting rock	Sublevel drifting & X-cutting rock	Raising two compart. rock	Raising single rock
Size of opening	9 x 9	8 x 8	5 x 8	5 x 7	4 x 8	4 x 5
Timbered or not	8'tbr.	None	3½'cap 7'post	None	6"crib.	None
Physical Properties	Med. hard	Hard	Med. hard	Hard	Hard	Med. hard
A. LABOR (man-hours per foot)						
(a) Breaking (drill. & blast.)	4.89	6.22	3.38	4.54	7.09	6.38
Timbering	3.07	-	2.18	-	5.94	-
Mucking	3.15	2.67	2.39	1.95	-	-
(b) (Haulage & hoisting) total	-	-	-	-	-	-
(Supervision) only	-	-	-	-	-	-
Total labor	11.11	8.89	7.95	6.49	13.03	6.38
Feet per 8-hr. shift	.720	.900	1.005	1.232	.614	1.253
(a) Trimming, headboards, preparations, etc. included.						
B. POWER & SUPPLIES (per foot)						
Explosives (lbs. per ft.)	17.6	19.35	9.67	9.30	13.67	8.61
Timber (b. m.)	64	-	37	-	60	-
(c) TOTAL POWER (kw.h.)						
1. Air compression	-	-	-	-	-	-
2. Hoisting	-	-	-	-	-	-
3. Haulage	-	-	-	-	-	-
(d) Other supplies in per cent of total power and supplies	-	-	-	-	-	-
(e) C. LABOR (per cent) total cost						
Labor, including supervision	-	-	-	-	-	-
Power and supplies, including comp. air, drill steel, etc.	-	-	-	-	-	-

(b)-Total on next page. (c)-Total on next page. (d)-Total on next page. (e)-Total on next page.

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Table 3-A - Detail of Costs in Units of Labor, Power, and Supplies (Cont'd.)
Ore Development

NOS. 5 & 6 SHAFTS	Main level drifting & X-cutting ore	Sublevel drifting & X-cutting ore	Sublevel drifting & X-cutting ore	Raising two compart. ore	Raising single ore	Raising single ore	TOTAL ALL DEVELOP-MENT ROCK & ORE
Sublevel overhand open stoping							
Size of opening	9 x 9	5 x 8	5 x 7	4 x 8	4 x 4	4 x 5	
Timbered or not	8'tbr.	3½'cap 7'post	None	6"crib.	6"crib.	None	
Physical Properties	Med. soft	Med. soft	Med. hard	Med. soft	Med. soft	Med. soft	
A. LABOR (man-hours per foot)							
(a) Breaking (drill. & blast.)	4.03	1.56	1.83	4.16	2.60	3.23	2.88
Timbering	3.25	1.39	-	4.00	2.23	-	1.00
Mucking	3.22	1.97	2.02	-	-	-	1.65
Haulage & hoisting) total	-	-	-	-	-	-	1.58
Supervision) only	-	-	-	-	-	-	.47
Total labor	10.50	4.92	3.85	8.16	4.83	3.23	7.58
Feet per 8-hr. shift	.762	1.627	2.075	.930	1.657	2.477	1.447
(a) Trimming, headboards, preparation, etc. included.							
B. POWER & SUPPLIES (per foot)							
Explosives (lbs. per ft.)	16.3	6.0	6.2	6.1	5.6	6.0	8.4
Timber (b. m.)	64	37	-	60	30	-	15
TOTAL POWER (kw.h.)							
1. Air compression	-	-	-	-	-	-	37
2. Hoisting	-	-	-	-	-	-	22
3. Haulage	-	-	-	-	-	-	3.4
Other supplies in per cent of total power and supplies	-	-	-	-	-	-	23
C. LABOR (per cent) total cost							
Labor, including supervision	-	-	-	-	-	-	62
Power and supplies, including comp. air, drill steel, etc.	-	-	-	-	-	-	38

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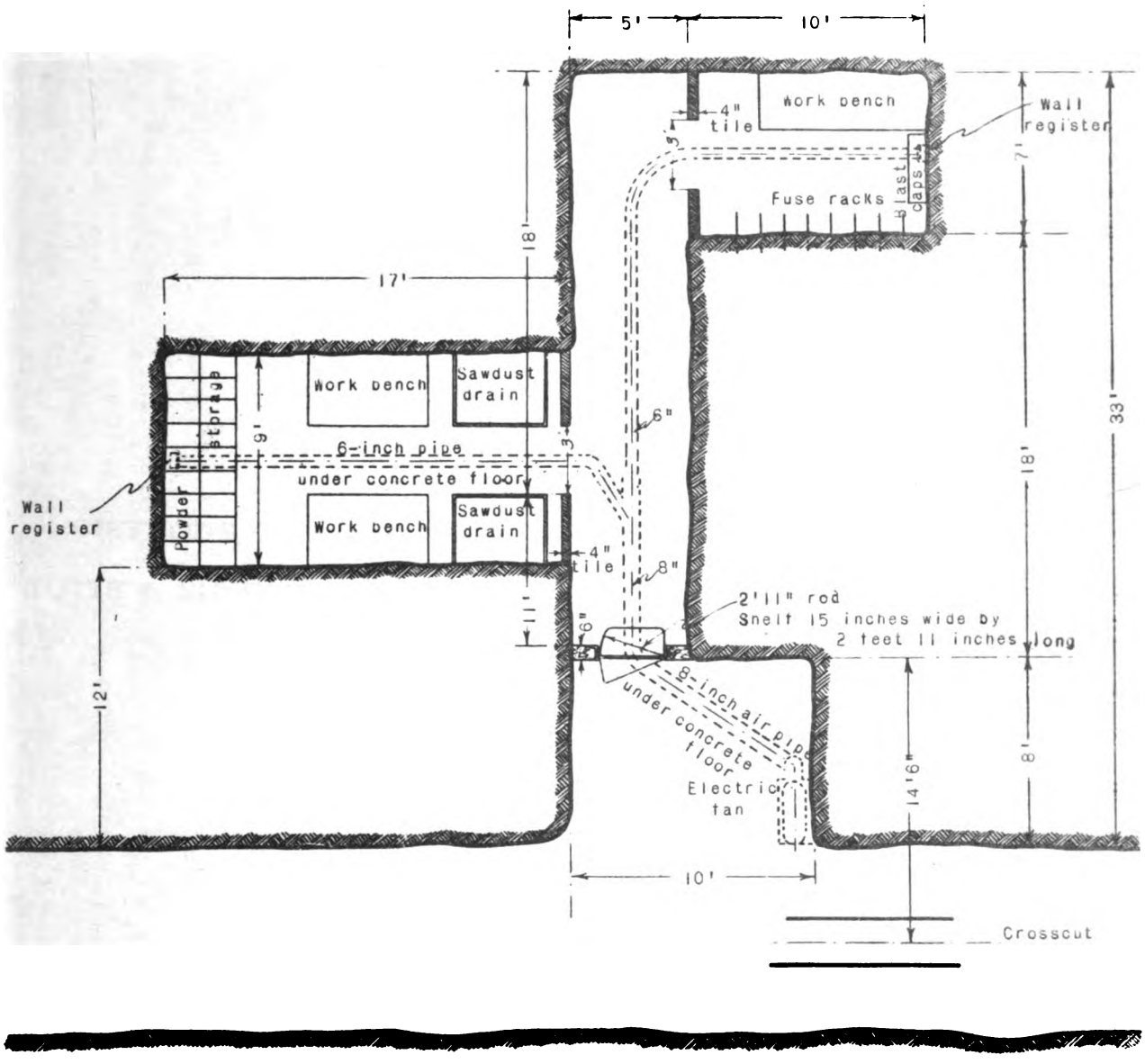

Figure 51.- Underground powder house

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